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TECHNOLOGY REVIEW

JUNE 2001

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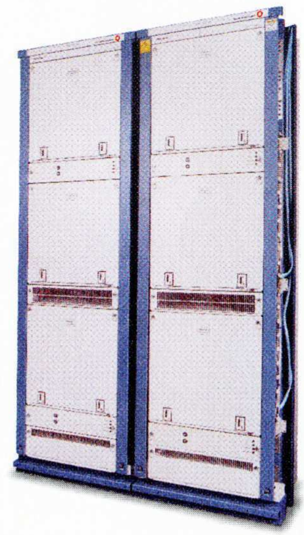

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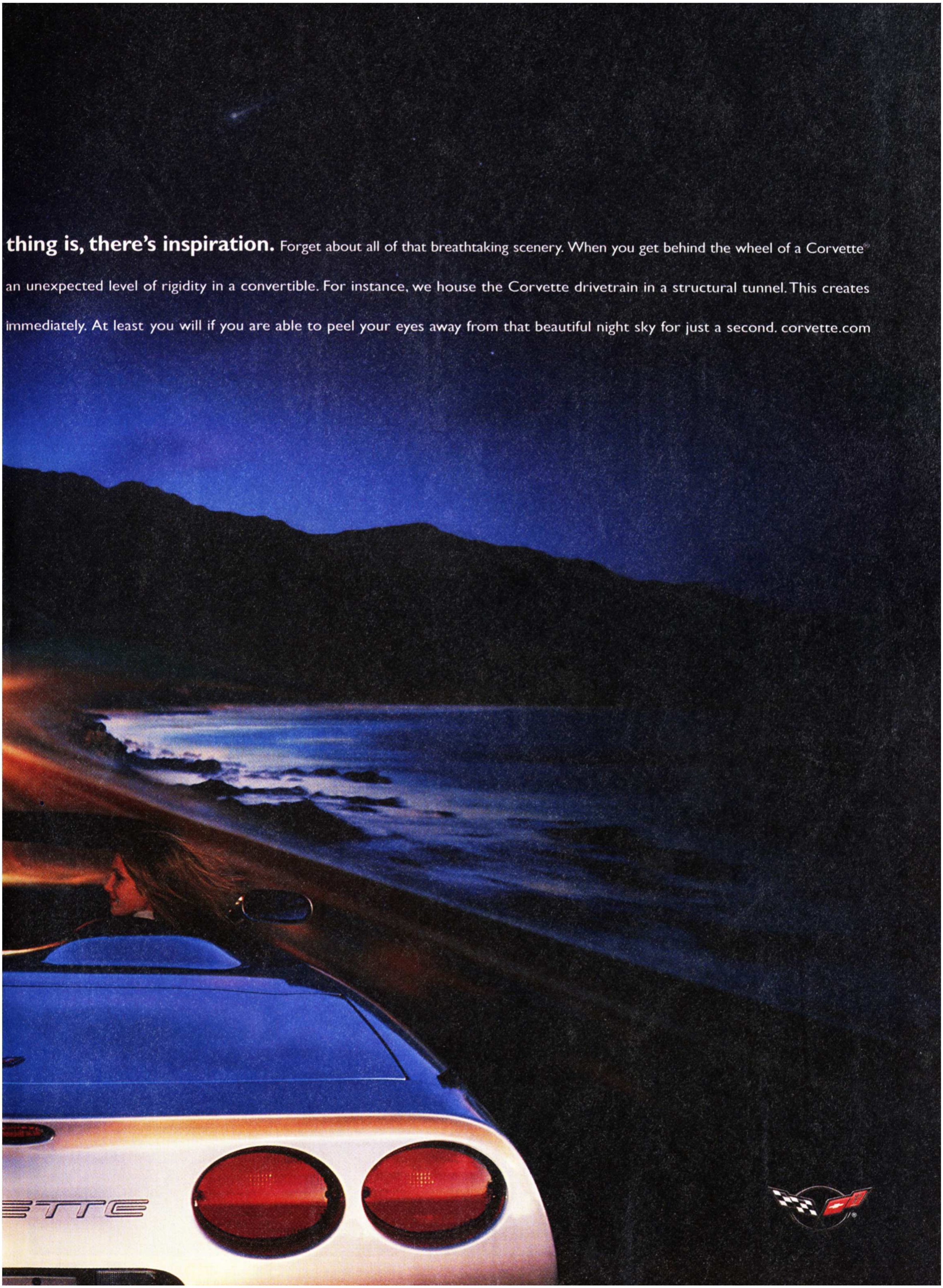
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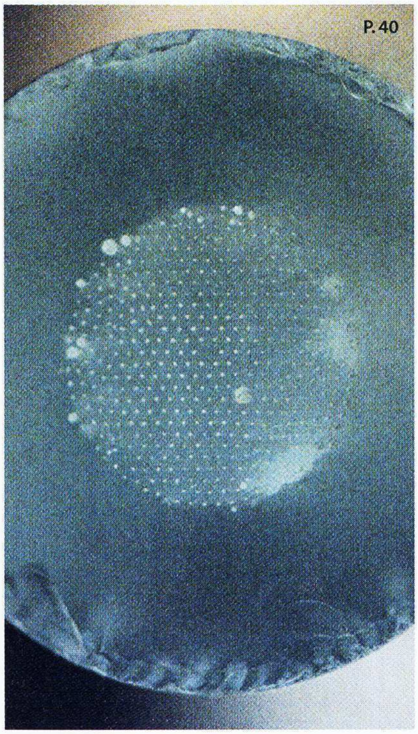

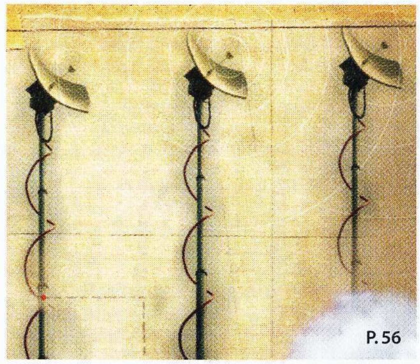

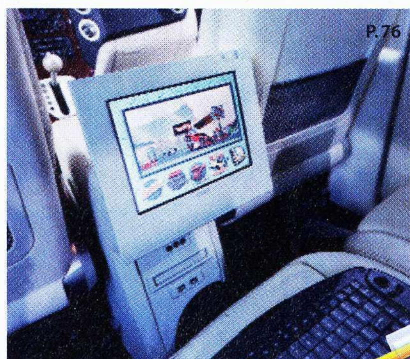

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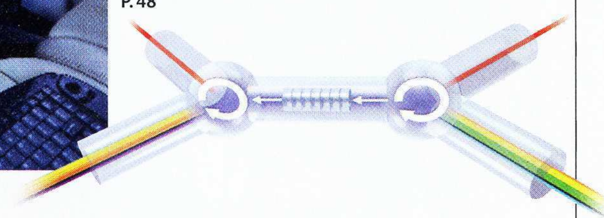

SPECIAL ISSUE: WIRED+WIRELESS

We've turned into information junkies. Now optical fibers and airwaves are straining under the load. *TR* spotlights the hottest technologies for expanding capacity and examines how bandwidth will be used.

FEATURES

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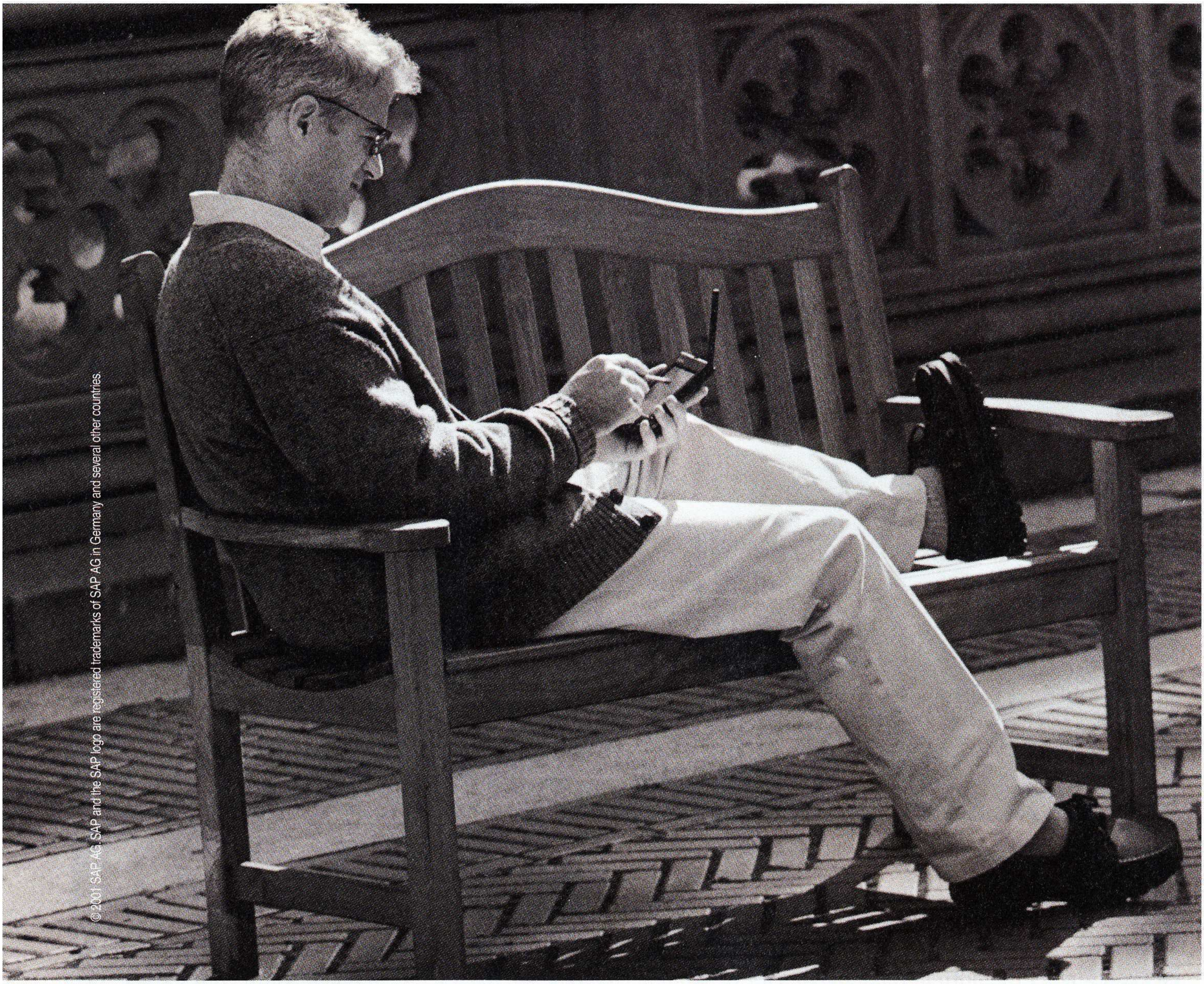
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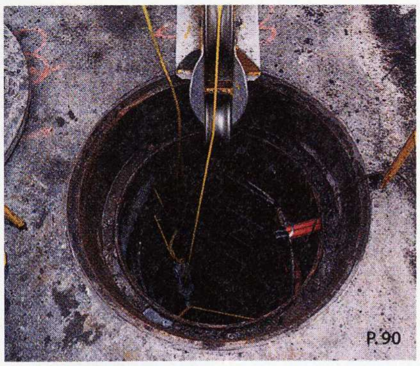

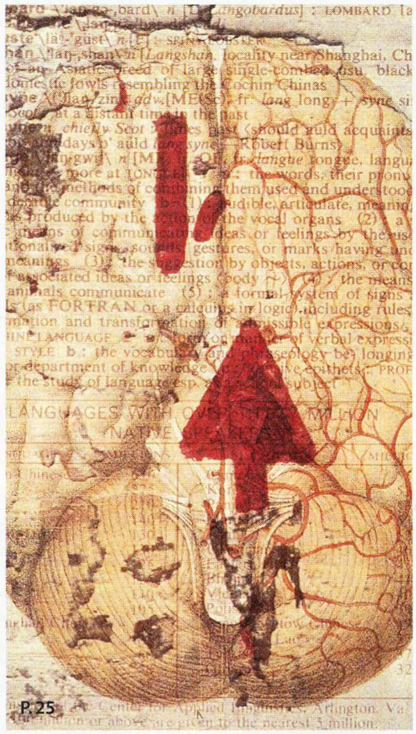

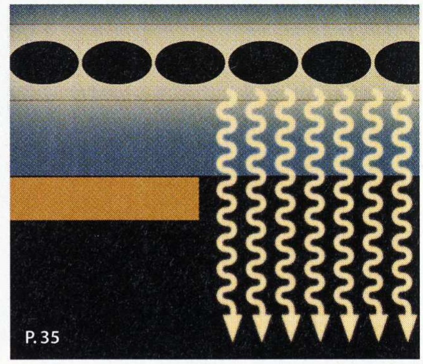

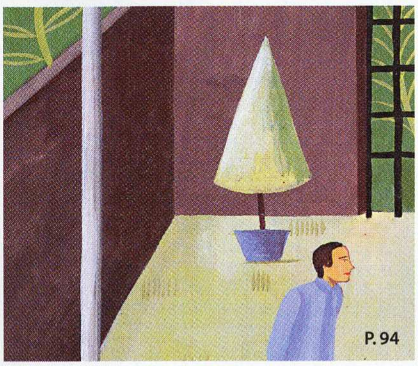

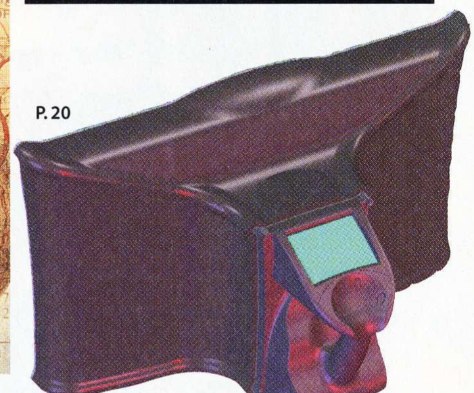


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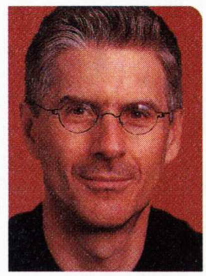
Boom + Bust

HERE'S A TYPICAL TECHNOLOGY TRAJECTORY: AT FIRST THE NEW technology is the property of a few visionaries and engineers. They do their best to bring it to market and spread the appetite for it. They succeed. Too well, in fact, and in a few short years, the general public is sold on the revolutionary promise of the new way of doing things. Investors and consumers expect the world to change—and fast. But the payoff can't keep up with the public appetite, and pretty soon public expectation crashes, coming to rest way down below what the payoff might ultimately be. The technology itself, however, just keeps chugging along, and a decade or two later—presto, the revolution does happen. But by then, everybody's forgotten about it. It's just part of life.

That generic fable of boom and bust describes lots of technologies. Think of electricity. Or the automobile. Both roused enormous hopes, disappointed many people, then more quietly transformed just about everything. The same is true of the bandwidth revolution now underway.



A year or so ago, we were all enticed by visions of the "wireless Web." Soon, the prophets said, we would be getting access to the Web on our handheld devices everywhere we went. And then, they added, we would get "true broadband," which meant full-motion video on our cell phones, along with just about any other kind of information our hearts might desire. This broadband revolution would be underpinned, they told us, by advances in fiber optics that would make bandwidth so cheap providers wouldn't even bother to charge for it anymore. Instead, they would charge for other services.

This vision got a lot of people hopped up, and some of them went out and paid premium prices for the stocks of the companies that were making the optical switching equipment needed to make the dream come true. When it turned out that those equipment makers weren't going to make quite as much money in the short term as some had said, the markets turned sour on them.

So now we're in the "down" phase of the technology introduction cycle when it comes to "Wired + Wireless." The realization of the dream is going to take longer than some folks thought. And it's maybe not going to happen in quite the way it looked a year or so ago. Our attitude is: so what? The promise of this technology is just as great as it was then. Beneath the boom and bust cycle of overheated expectations, the growth of wired and wireless technologies, along with the applications that accompany them, and the interfaces needed to enjoy them, is steady. That's what this issue covers.

If you read it with care, you'll find out where the real advances are taking place. Many of them are in the cutting-edge research that's going on in the telecom "backbone" *("Building a Better Backbone," p. 40)*. Breakthroughs are needed before we really get to broadband, though *("Breaking the Metro Bottleneck," p. 48—and "Little Big Screen," p. 64)*. Furthermore, the final picture will differ from the first enthusiastic dreams. For example, the vision of streaming video on demand everywhere may never materialize *("Mobile Web vs. Reality," p. 56)*.

In preparing this issue for you, we've penetrated both the breathless hype *and* the exaggerated gloom to give you a snapshot of a revolution in progress. And that's what we promise to do in every issue of *Technology Review*: Cut through the wild overreactions technology provokes and describe its real, enduring impact.

—John Benditt

TECHNOLOGY REVIEW

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John Benditt

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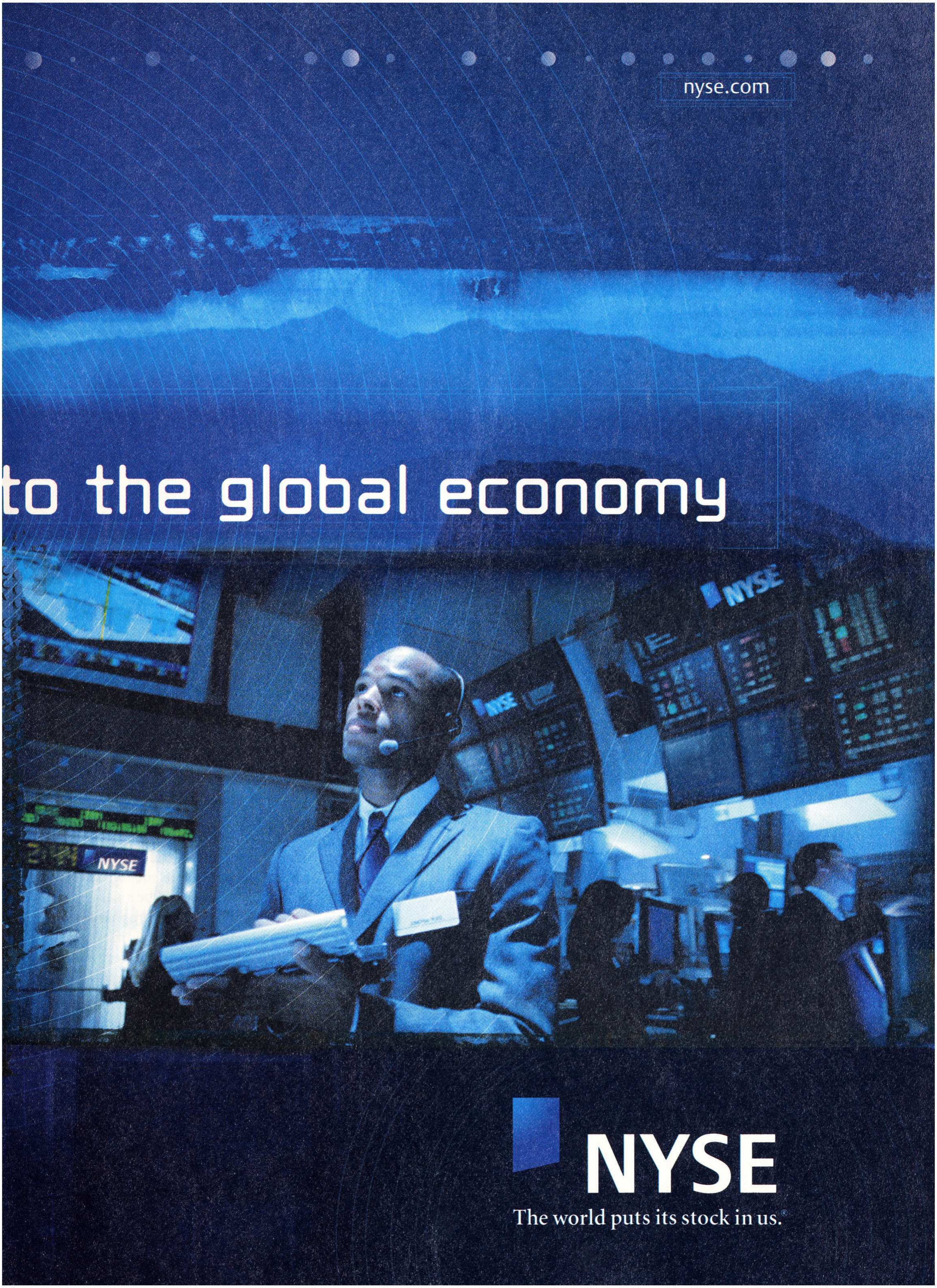
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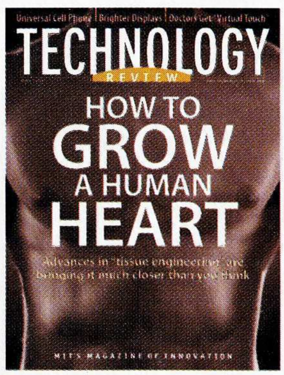
"Without patent protection, no [pharmaceutical] company would be dumb enough to develop a drug for AIDS or any other disease."

Patents Not the Problem

SETH SHULMAN'S ARTICLE "IN AFRICA, Patents Kill" (*TR* April 2001) casts drug companies as villains because they make so much money. However, he never mentions the billions of dollars in research and development they spend making effective medication. Nor does he mention the billions of dollars they lose developing drugs that ultimately don't work. By only looking at the manufacturing costs, he presents an extremely misleading perspective on the drug industry.



From this misleading perspective, Mr. Shulman argues that since these drug companies make such apparently obscene profits, they should allow patent violations to occur when there are serious epidemics. While I believe it would be honorable for these companies to offer some humanitarian aid to Africa by giving away medication or at least selling it cheaply, I think it would set a dangerous precedent to simply ignore patent laws. Not only would this prevent the drug companies from recouping their billions in research and development, it would discourage them from developing medicines for other serious epidemics, since they would fear losing money when their patent rights were taken away "for the greater good."

DAVID MUSICK
Salt Lake City, UT

I DISAGREE WITH SETH SHULMAN'S column "In Africa, Patents Kill." Patents don't kill, the AIDS virus does. Not once does the author mention preventative and educational measures that can be used to slow the progress of AIDS. Instead, he resorts to smear tactics by attacking entities that in no way have contributed to the problem. In fact, these firms have spent billions of dollars developing drugs to treat AIDS. Without patent protection, no company would be dumb enough to develop a drug for AIDS or any other disease. Much of the blame should be placed on others that have not provided the counseling, education and prevention that could reduce the spread of AIDS.

FRANK DILORENZO
New York, NY

AS I READ SETH SHULMAN'S ARTICLE, I had to cringe. To claim that the epidemic could be stemmed by the suspension of patent rights is not only simplistic, it is outright false.

Even if the drugs were free, they would be no panacea. Only 50 percent of AIDS-infected Americans are able to tolerate all of these highly toxic and complicated therapies. So how could they be anything but marginally successful on a continent where safe water, health clinics, specialized foods and adequate follow-up and support are extremely lacking?

Although it is rarely reported, some pharmaceutical companies have agreed to slash AIDS-drug prices in Africa, but with certain stipulations. These include demanding that infrastructure be in place to test for HIV and that drugs not be siphoned off to the international black markets.

As for Cipla, the Indian generics company Shulman puts on a pedestal, it charges $350 to $600 per year for what is only a small portion of a complete AIDS cocktail. While $350 to $600 may sound cheap, that is more than 60 percent of an average African's yearly income. This places the Cipla drugs way out of the reach of most Africans.

Economist Jeffrey Sachs has estimated that five million out of the 25 million infected Africans could be saved over the next five years if about five to ten billion dollars were poured into the continent. This is not chump change and highlights the fact that pharmaceutical companies could not possibly "fix" the epidemic without a concerted global push. To isolate them while conveniently ignoring the responsibility of our own governments and the United Nations shows Shulman's argument to be more rousingly ideological than practical.

ROSE SHUMAN
Providence, RI

THE FREE-ENTERPRISE SYSTEM THAT works so well does not distinguish between companies that make luxuries and those that make necessities. If only we could implement Mr. Shulman's suggestion that companies charge what people can afford to spend, then perhaps I could have the yacht, the mansion and the Lexus. To be sure, these items will not save lives; but to find the cure for AIDS that will, we must be very careful not to kill the geese that lay the golden eggs.

BUCK GIBBONS
Bishop, CA

Seth Shulman responds:
I've been overwhelmed and gratified by the volume of feedback over my column on AIDS in Africa, and I thank readers for their many thoughtful responses. My intent was never to pretend for a moment that the pandemic will be an easy problem to solve or that my proposed "state-of-emergency" suspension of patent rights in the region would offer a panacea in itself. I certainly agree that the overwhelming problems of poverty, availability of potable water and scarcity of health-care professionals are first-order questions that desperately need to be addressed. Nonetheless, I stand by the thrust of the column as a matter of principle. My main point is that, important as intellectual-property rights may be for spurring innovation, the AIDS crisis in Africa challenges us to do more to disseminate our life-saving technology in the face of such a deadly threat. A flurry of

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activity on this issue in recent weeks—by drug companies, governments and international agencies—marks a welcome and promising start.

Dim Displays

BOTH BOB JOHNSTONE'S ARTICLE ABOUT "A Bright Future for Displays" (*TR* April 2001) and his sidebar, "Global Race for a Better Display," are based on the assumption that smaller is always better. I predict that in 10 years you will have articles entitled "Innovative Ergonomic 17-inch Diagonal Monitors Replace Tiny PalmTop Screens That Cannot Be Read by Humans," "Doctors Unsuccessfully Reduce the Human Focal Distance to a Centimeter and Resolution to a Micron" and "Medical Attempts to Graft Pin-Sized Finger Attachments Fail."

BLANCHARD D. SMITH
Alexandria, VA

AT 200 HOURS, I THINK THE MOBILE-phone industry underestimates the typical yearly use of cell phones. In the past month, I have had my phone on almost constantly during the day, which means I would have it powered up for approximately 170 hours. Most of that time the phone would have been on standby. Still, over a year, you are giving me a dim forecast of how long my bright and colorful display will last.

I was not thinking of running out and buying another $300 cell phone every 200 hours. Tell Motorola and Kodak that they are going to have to do better than that.

NANCY R. RANKIN
Boulder, CO

The End of Free Music...Not!

I CAN'T COMPREHEND WHY THE COMPANIES mentioned in Claire Tristram's "The End of Free Music?" (*TR* April 2001) are spending so much time and money developing Content Protection for Recordable Media technology, which will only keep honest people honest. All it takes is media-capturing software to snag a file and save it in whatever format you want. In fact, there are a number of ways of getting around content protection. Who are these companies fooling?

A commonly overlooked phenomenon in this industry is that a lot of

people pay for the same thing more than once. How many people have purchased a record, then tape and then CD of the same music compilation? How much more money for how many more formats should these people have to spend? And everyone knows that the record labels get the majority of the money.

The real key is to make the content good enough to buy at a fair price in the first place, and to stop paying record companies so much money. Bottom line: produce a good product and lower its cost, and people will stop stealing it. It's that simple.

DENNIS MARCUM
Alpharetta, GA

YOUR ARTICLE "THE END OF FREE Music?" was quite interesting but lacking in one respect. No matter how good a copy-protection scheme for music may prove to be, the system will remain easily broken into. The decryption procedure may take a few minutes, but once the encryption is gone, the break-in need never be repeated.

JAMES ANDREWS
Hudson, OH

No Joke

THE NOTION THAT "THERE'S NO CURE for [the] aging" that causes PCs to crash so often is so ludicrous that I'm still not sure that Eric S. Brown's "Predicting the Crash" (*TR* April 2001) wasn't an April Fool's piece. Under the minuscule loads that most PCs carry, the risk of aging ought to rank below the probability of a power failure.

Helping users adapt to the unacceptable quality level of PC operating systems can only postpone the day when we wake up and break software vendors' unique immunity from liability for negligent design.

DOUGLAS MCILROY
Etna, NH

Squeezing the "Live" Out of Music

YOUR "MP3 SOFTWARE" ARTICLE (*TR* April 2001) states that MP3 technology enables substantial compression of audio files "without sacrificing the quality of the listening experience," which simply is not true. Overtones, harmonics and different frequencies give sounds of any kind their "live" qualities. All current technologies for compression and decompression of audio sacrifice most or all of these characteristics to speed and efficiency. Do not be fooled by anyone's claims of "lossless" or "CD-quality" compressed audio. Simply stated, it is not being done yet, as any decent audio laboratory can demonstrate quite easily.

THOMAS NORTON
Easton, MD

Time on the Superhighway

ANDREW ODLYZKO'S "THE MYTH OF 'Internet Time'" (*TR* April 2001) was interesting, illuminating and an excellent summation of where we are now that the high-tech bubble has burst.

But I think he is somewhat off the mark. The Internet was supposed to be the Information Superhighway. Web site developers have been concentrating on the traffic, its speed limits, increasing those limits, the safety of the road, its width, what it is made of, where it is going financially, etc. What about the "information" part? Interesting, simple content is what this Internet is about.

Commerce, selling, all that stuff will follow if you give the people usable information. That's what the Internet is for.

HOWARD KANE
Forest Hills, NY

I DON'T THINK ANDREW ODLYZKO should write off the concepts of "Internet time" and "first-mover advantage" as misunderstandings of Internet reality. On the contrary, these concepts accurately reflect dynamics of the marketplace.

"Internet time" refers to the speed at which consumers can shift their loyalties between competing Web sites and free software products. On the Internet, a large stabilizing factor in brick-and-mortar stores—location—is not present. On the Internet, sites are judged and compared against each other directly. A single difference in an important feature can result in a quick exodus from one site to another in a much shorter time than is seen in physical stores. The death of AltaVista is a good example of the quick fall a Web site can experience.

The "first move" makes more of a difference on the Internet because of the leveling of the playing field among companies. Location doesn't matter; loyalty is based more on the value provided by the immediate feature set.

BEN HOUSTON
Ottawa, Ontario

I APPLAUD MR. ODLYZKO FOR HIS insightful views, but he overstates his claim. It is impossible not to notice that the pace of life, both human and silicon-based, has accelerated. Why, then, is it so hard to believe that time is more important than ever?

In markets where technology development cycles are key, validation by early adopters can significantly affect corporate success over the long term. This disjunction between the rate of adoption by the majority (which lags) and the leading edge (which pushes closer to the development window) means that the importance of high velocity is significantly greater for technology vendors (and their investors) than for technology users.

Agility can enable upstarts to exploit a market position before the slower companies can. Take GEICO, for instance. It was able to exploit a new technology-based sales channel (telephone-based direct sales) to become a leader in automobile insurance. The incumbents were left to catch up, forestalling copycats. GEICO would be a small fraction of its current size had it relied upon building an agent-based distribution network.

PAUL KRIEG
Reston, VA

Tower of Technology

I ENJOYED HENRY JENKINS'S "INFORMATION Cosmos" piece (*TR* April 2001) and suggest that it might also be titled "Information Chaos." We are awash with data, facts, figures, images and sound. In fact, one is hard put to distinguish among hypothesis and theory, diagnosis and prescription, fact and fancy. Thus, while I agree with Jenkins in his concern that a library might be "compromised by social and political forces beyond its control," I am much more worried about information becoming our Tower of Babel. No revolution or counterrevolution would be able to overturn it because we are all busily adding to it click by click.

LEO MOLINARO
Philadelphia, PA

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STRAIGHT FROM THE LAB: TECHNOLOGY'S FIRST DRAFT

A Cheaper Image

Positron Emission Tomography (PET) scans have long been used for brain imaging. Now clinicians have also started using them to detect cancer. The accuracy of these 3-D imaging systems could reduce the need for biopsies and invasive surgery. However, each machine costs up to $2 million; as a result, only a few hundred machines in the world are up and running. Acton, MA-based PhotoDetection Systems has developed a PET system that could cut the cost in half—and detect tumors with greater resolution. Like other PET machines, the new system uses a crystal to convert gamma rays (the high-energy photons emitted from an injected radioisotope in the patient's body) to light. But instead of using more than a thousand pricey photosensors to read the light, it relies on an array of optical fibers to pinpoint the position of the light emerging from the crystal. The machine can then detect tumors as small as four millimeters in diameter, as well as larger but less active tumors that would normally go undiagnosed. The company hopes to have a machine ready for testing by mid-2003.

Car Compost

VITO ALUIA

Environmental groups want automakers to build cars that can be scrapped in eco-friendly ways. Metal parts are easy to recycle, but tough, durable automotive plastics aren't. Now engineers at the University of Warwick's Warwick Manufacturing Group in Warwickshire, England, have found a way to make these plastics "greener"—using elephant grass.

Working with Somerset, England-based Bical, Warwick engineers have used previously discarded pieces of elephant grass to stiffen biodegradable plastic resins not previously suitable for use in cars. The resulting plastics are strong while in use yet can be encouraged to biodegrade in compost heaps. The group has already tested wheel rims made from the plastics; several European car manufacturers have expressed interest.

Seeing through Walls

COURTESY OF TIME DOMAIN

It's a regrettably common scene: hostages at gunpoint, police shouting through bullhorns, holding off for fear of harming those inside. Now Huntsville, AL-based Time Domain has a device that could give the cops a better sense of when to move in: an instrument that can see through walls. Much like a radar set, the system sends out a signal that bounces off objects, so distances can be calculated. But while radar sends out a continuous wave, Time Domain's instrument sends out millions of pulses per second, allowing it to screen out still objects and precisely locate moving objects. The device, which the company expects to sell by year's end, will be responsive enough to detect even the minute motions of a person attempting to stand still. An even more sensitive version is being developed for use in finding people during earthquake rescue.

Ankles Away

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Sidelined with an ankle injury and looking to rehab without visits to a therapist? Soon you may be able to strap on a mechanized device that allows your therapist to monitor your exercises online. Once hooked up to the Rutgers Ankle, built at Rutgers University's Human Machine Interface Laboratory, your injured foot rests on a platform that stands on six pneumatic cylinders. The cylinders deliver forces to the platform to move the foot or restrain its movement. Specific exercise-simulation software prescribed for the patient regulates the forces and records the resistance offered by the foot; a therapist can monitor the session online. To beat boredom, the software integrates games with the exercise—for instance, ankle movements can operate a flight simulator. The Rutgers lab expects clinical trials to begin within a year.

Fuel Cells Clean Up

Vacuum maker Electrolux has recently partnered with New York's Manhattan Scientifics and Lunar Design in San Francisco to develop the first fuel-cell-powered vacuum cleaner. It will use a hydrogen fuel-cell technology developed by Passau, Germany-based NovArs. The stacked cylindrical fuel cells—made of lightweight carbon-composite materials held together with sealants instead of bolts and screws—weigh in at only 780 grams each. The cells generate electricity using hydrogen, which passes through a membrane, giving up electrons in the process. The electrons create a charge as they move through a circuit. The fuel cells can power a 1,000-watt motor for several hours of continuous operation, something not possible with rechargeable lead-acid batteries. When the vacuum's power is exhausted, its hydrogen tank can be replaced as easily as the propane bottle on a barbeque grill. Electrolux plans to begin selling the 4.5-kilogram vacuum cleaner in a backpack model next year.

Smart Knee

For above-knee amputees, today's artificial knees are vast improvements over their counterparts of just a few years ago. But even these advanced prosthetics have limits: they can't adapt to a patient's natural way of walking or to changing terrain, like sudden steep hills or varying surfaces.

Researchers at MIT's Leg Laboratory in the Artificial Intelligence Laboratory have developed a prosthetic knee that can adjust to these situations. With built-in sensors, the device detects the position of the knee in space and all the forces applied to it. The sensors transmit the information to a microprocessor within the knee, which sends a signal to an actuator that modulates the knee's mechanical behavior. If a person fitted with the artificial knee moves from, say, cement to tall grass, the sensors detect that the knee has less forward speed and is no longer swinging as easily; the system then compensates for the change. The new device represents a dramatic improvement over the most sophisticated current system, which requires that users connect the knee to a separate computer each time they need to change its settings. Flex-Foot, a maker of leg prosthetics based in Aliso Viejo, CA, is commercializing the Leg Lab's electronic knee. The company hopes to have a product in beta trials next month.

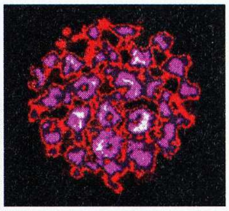
Dwarf Drones


CURTIS BOGGS

Since the 1970s, the U.S. military has used unmanned airplanes to see behind enemy lines. But each of these "drones," which cost upwards of $15 million apiece, provides strategic intelligence only to top-ranking officials. Real-time surveillance information rarely makes it to the commander on the battlefield's front line. The Marine Corps Warfighting Laboratory is on the verge of changing that.

In collaboration with the Naval Research Laboratory, the Marine Corps plans for the first time to deploy miniature, autonomous unmanned air vehicles. Each of the 73-centimeter, 1.9-kilogram spy planes—dubbed Dragon Eyes—will carry an infrared imager, a wireless communications link and Global Positioning System software. Field soldiers will be able to assemble the five-piece plane on the spot, program the flight path, launch the craft with a flick of the wrist and view a real-time video image of enemy territory. The Marine Corps will hold field trials in the first half of 2002. Full-scale production of 1,000 units should begin by early 2003.

Virus Fighter


COURTESY OF ORIGENIX

Each year, more than five million people in the United States are infected with human papillomavirus—some strains of which can cause genital warts and cancers—during sex. One of the most common causes of sexually transmitted disease, the virus is highly contagious, and so far, nobody has come up with a way to fight it directly. Doctors can remove the warts with chemicals, lasers or other means, but the virus isn't affected. Now Quebec-based Origenix Technologies is testing a drug the company believes will combat both the warts and the virus by blocking the microbe's ability to replicate.

The drug is a specially modified DNA molecule that interferes with one of the genes the virus uses to replicate itself once it infects a human cell. Origenix has completed animal testing of a cream containing the drug, says executive vice president Anthony Payne. The company hopes to begin U.S. clinical trials this summer.

How Know Mad Cow?

One factor contributing to the spread of mad cow disease is the lack of an effective way to detect the malady's presence before infected animals begin showing symptoms. Currently, the only reliable way to confirm a diagnosis is with a brain biopsy or autopsy.

Michael Clinton and colleagues at the Roslin Institute in Scotland have found a clue that could yield a simple blood test. Clinton discovered that the level of a protein called erythroid differentiation-related factor was dramatically lower in blood from infected sheep and bone marrow from infected cattle. But it could still be awhile before a commercial blood test is generated. The researchers are trying to confirm their initial findings in a large set of animals as well as in humans. If all goes well, they expect to begin developing a diagnostic test.


STONE

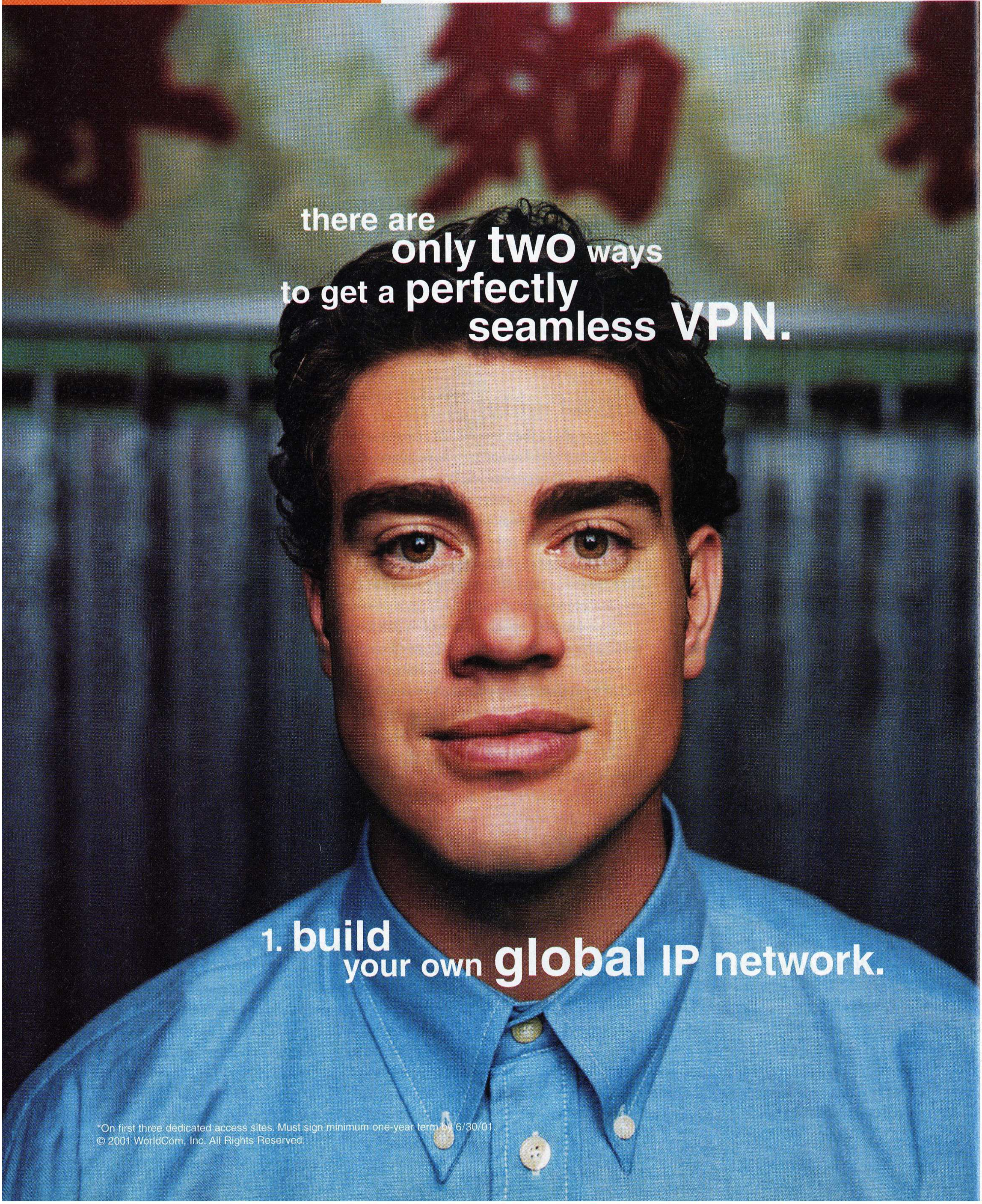
Tower Power

The towers used to relay calls to cell-phone users are sprouting everywhere. But the skyrocketing demand for cell phones and for wireless Internet access overwhelms the relay stations' capacity as fast as companies can erect them. A radio-frequency transistor technology created by electrical engineer Jayant Baliga at North Carolina State University could help stem the tide by allowing towers to handle 10 times their current signal capacity.

Baliga says his new chip design will make the transistors used in relaying calls cheaper and smaller, and it will boost the power of the towers' signal amplifiers as well. That should allow wireless stations to handle more calls at once, send data faster and help avoid the interference that occasionally results in users overhearing others' conversations. Baliga has founded a company called Silicon Wireless in Raleigh, NC, to commercialize the technology and has received funding from Fairchild Semiconductor. The first chips using the transistors could be in cell towers by the end of the year.

WORLDCOM

Alex Kowalczuk
IP VPN Services



Waiting for Linguistic Viagra

WOULD YOU RATHER BE BLIND or deaf?

I love those classic conversation starters. Has Earth been visited by extraterrestrials? Does President Bush need to carry money? Why is it that, after making love, men fall asleep and women wake up?

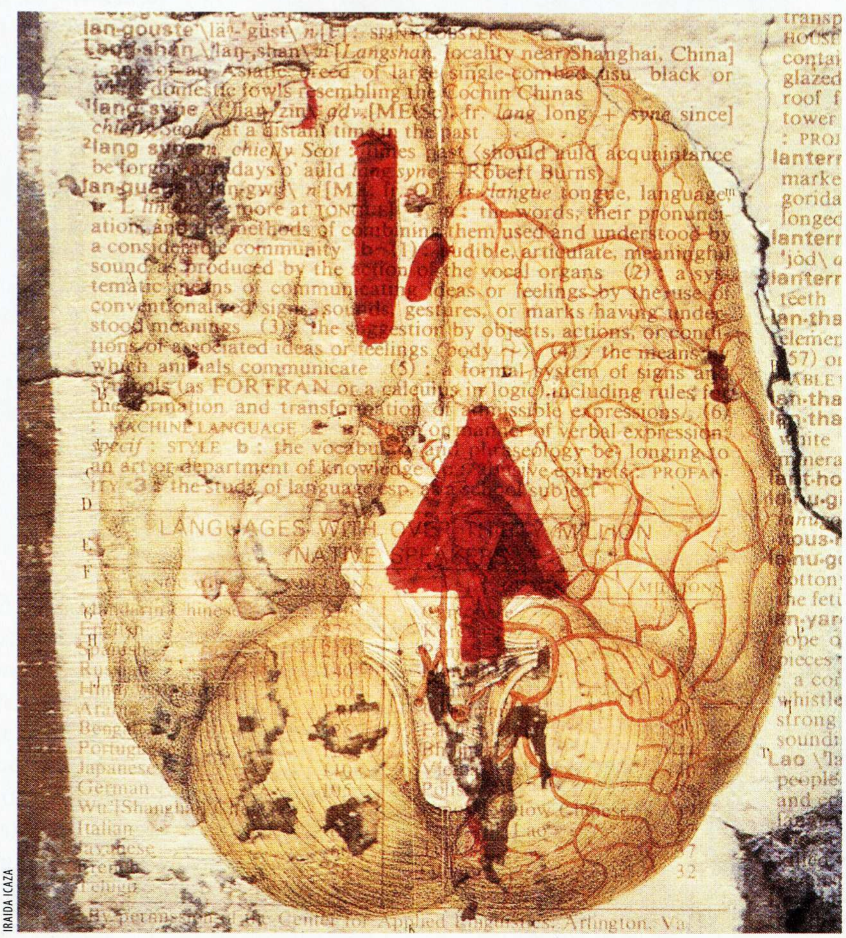
Let's focus on the blind/deaf question. Genius overcomes many difficulties. As evidence, we have the pantheon of blind and deaf artists, ranging from Beethoven to Goya to Milton to Ray Charles. According to neuropsychologist and author Oliver Sacks (in his book *Seeing Voices*), whether it's better to be blind or deaf depends on how old you are. For an adult, blindness and deafness are about equally problematic. But for a child, there is no question: it's better to be blind. Anyone who has had the opportunity to teach a deaf child knows this. Hearing is the primary channel through which we receive language, and all of those incoming words downloaded into our brains carry a wealth of emotional and cognitive apparatus that structures and empowers our imagination. Language is the mind's opposable thumb.

Whether it is a book, a pencil or a computer, technology deeply affects the way we learn, and interact and create with, languages. The word "hello" came to prominence in English because of the telephone. Or consider the emergence of mass public literacy. It wasn't born in a vacuum. It is largely a technological by-product of the printing press—and it's been greatly affected by the rise of television and other media that compete for our attention. The question is, how will future information tools influence our relationship with languages?

David Sarnoff, an early president of RCA, believed that the broadcast of radio and television would spread English as the world's unifying language. It did and it does. More recently, the World Wide Web has further fostered English as the global lingua franca. Visit a developing country and you find that people seeking better lives see two clear paths: learning English and mastering computer skills. The two are intertwined.

Historically, technology has had a huge impact on the use of language. Around 1811, the steam engine collided with the printing press, and the result was as explosive then as the collision of computers with the telephone network is now. The rotary-driven steam press printed hundreds of times faster than any other available technology—so fast that publishers couldn't afford to feed enough paper into those voracious machines. In the 1850s, some clever Germans invented a cheap pulp papermaking process. The new stuff became known as newsprint, since that's largely what it was used for, and with the force of this flow, the modern newspaper took shape.

Soon it became clear that paper was no longer the scarce resource. Nor were printing presses, or even news. The scarce resource? Readers. In 1858, only one in 20 British army recruits could read. Other European societies had similar levels of literacy. And so, in countries across Europe, as well as in America, policymakers began mandating more systematic schooling. By 1900, literacy among British recruits had jumped to more than 85 percent and the novel had become a mainstream art form. Mass public literacy, therefore, was an outgrowth of a burst of technology that liberated a huge quantity of text, and then encouraged an ensuing ballet of



IRAIDA ICAZA

sorts among policymakers, educators, authors and printers.

If steam engines plus printing presses ignited a literacy revolution in the 19th century, what might be the combined effect of computers and telecommunications today? When the Web first self-assembled like the world's biggest set of tinker toys, the eyeopener was that the words and images on your screen were coming not just from your own local disk, but from disks on computers sprinkled all over the planet. As more and more bits piled up, the personal computer became like a soup strainer to filter chunks of useful information from the great wash of bits. Search engines like Yahoo! and AltaVista were followed closely by pidgin translation systems, which are interesting even in their fledgling state—and which will need to improve dramatically after two billion people in China and India come roaring online.

Literacy grew out of the collision of the steam engine and the printing press. What will the Net's linguistic impact be? We may be in for some real surprises.

What nobody can predict, of course, is what new intelligences will spin out of this computer-driven, massively global engine of cause and effect. Or how these developments will influence the language we speak.

We may be in for some real surprises. Will this process cause sophisticated artificial intelligence to finally burst onto the scene? Will the lingua franca dumb down from English into a sort of Internet Esperanto? Will cultures colliding online spur interest in other languages?

On the face of it, the prospects for another technology-induced upgrade in the popular use of language are not good. For one thing, computers have evolved into visual media. They are more deaf than they are blind: aural and linguistic interfaces lag far behind visual ones. What's worse, computers are coming out of an increasingly Anglocentric culture. Even at universities, fewer and fewer departments teach foreign languages and fewer students study them. Shockingly large numbers of U.S. elected officials have never traveled out of the country. The erosion of foreign-language study is a melancholy sight: there is nothing like learning another language to help you know your own more deeply. Whether it is calculus or Cantonese, you think differently in other languages, and those differences matter.

This linguistic ignorance dismays me because I love words. In fact, I'm a word nerd. I get a kick out of tossing a few odd ones into my column, just to see if the pervicacious editors will weed them out. Back in the late 1980s, I created one of the first computer dictionaries (with entries from Merriam-Webster's Collegiate Dictionary) on a NeXT computer. At the time, it was exciting to have hot-and-cold running definitions at your fingertips. You could click on any word that aroused your curiosity and my "Digital Webster" program popped up the definition. Isn't that the essence of the educational itch? First, having the appetite to know more; and second, actually satisfying that appetite.

One engineer used the dictionary to build an unbeatable Scrabble-playing program. Someone else tried to automatically translate the newswires into rap. I never got around to throwing Digital Webster at the *New York Times* crossword puzzle, but that kind of word play was what we hoped computer dictionaries would unleash. Sadly, it wasn't.

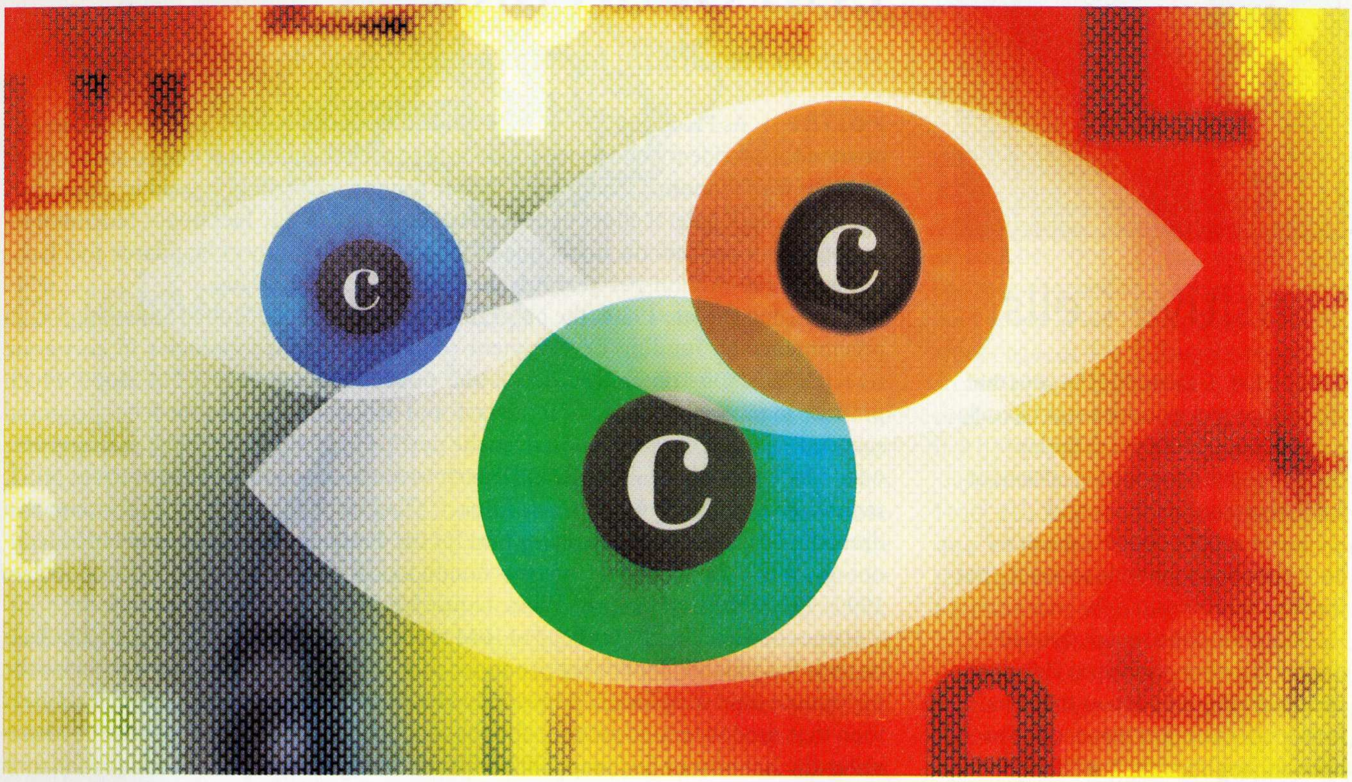
Recently, it seems as if information technology has become a sleeping pill for this sort of creative and constructive language hacking. Today's computers no longer come with a first-class, built-in dictionary; that feels like a step back. There are, of course, dictionaries online. But although you

can graze these canned Web dictionaries, you can't write programs to chew through them and do interesting things. The programmatic interfaces are closed. The pattern formed by networked PCs—the glut of Windows software, the lowest common denominator of Web servers—has become too much like the one-way information delivery of dumb cable television, and not as inviting even to word hackers like me. And writing teachers always bellyache about the insidious ways that word processors engender choppy, sloppy writing.

Maybe this is a lull. Maybe the current landscape of ugly displays, poor typography and flaky networks is too primitive compared to a beautifully printed magazine. But when the displays get really good, and when network connections are always available, like the air that we breathe—will we then see the emergence of a Napster of books to really shake things up? Can you imagine some hacker selling shoebox-sized pirate copies of the Library of Congress?

Perhaps we will wake up in a decade or two and the prevailing online language will be Cantonese. Perhaps it won't matter because computer and telephonic translation will have become so fantastically frictionless that worrying about Chinese copyright ripoffs will be superfluous. Ask to watch a spaghetti Western in Italian, and the system will not only translate the language on the fly, it will add the extra hand gestures, too. And maybe, if the biotech wizards get their way, we won't need all those clunky computers. I'm waiting for a linguistic Viagra pill that instantly makes you fluent in Italian, at least for an hour or two.

It's important to communicate. It's important to have a lingua franca. But it's also important to think differently. The most fertile, thriving cultures have a balance of order and chaos, with constant ferment. But today's computer media are flat and Anglocentric. Things are a bit too stuck, a bit too ordered. Both within the machines and across the network, we could enjoy a little more linguistic turmoil. TR



BRIAN STAUFFER

Pixel Perfect

Silencing critics—but still facing competition—Microsoft receives e-book patent

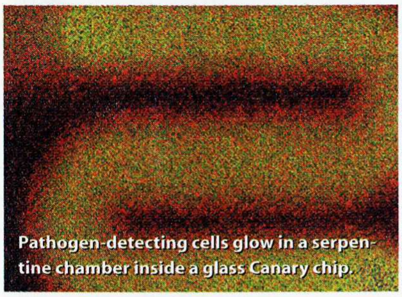
PATENTS | Three years ago, when Microsoft unveiled ClearType—software the company touted as a breakthrough in making type on a computer screen sharper and more readable—some observers cried foul. Former Apple programming consultant Steve Gibson, among others, charged that ClearType sounded a lot like a 1970s invention by Steve Wozniak for the Apple II computer. Despite the controversy, Microsoft has received its first major ClearType patent from the U.S. Patent and Trademark Office. The software giant says the new technology will be key in its attempt to revolutionize electronic books—portable computer screens displaying pages of text. Though it still can't match the sharpness of a printed page, ClearType improves the resolution of computer displays as much as 300 percent; it works best on liquid crystal displays but also improves cathode-ray tube displays, commonly used with desktop computers.

ClearType works through manipulation of the red, green and blue components of individual pixels (called "sub-pixels") to sharpen characters. To overcome color blurring, Microsoft developed an algorithm to filter sub-pixels based on their locations, illuminating those near a character's fringes differently than those at the center. The patent issued earlier this year is the first of more than 20 Microsoft expects to receive for the technology. "The importance of ClearType is that it lets us produce really readable type on existing hardware," says Microsoft researcher Bill Hill.

Armed with its first patent, Microsoft is strongly pushing ahead in deployment of ClearType. First released last August as part of Microsoft Reader software for electronic books, ClearType will appear in the next major release of Windows, future versions of the company's Pocket PC handheld computer, and a dedicated e-book device coming this summer.

Microsoft will have competition: in April, Amazon.com announced that it would start selling nearly 2,000 electronic books using Adobe Systems' rival eBook Reader software. Until that announcement, Amazon carried electronic titles compatible only with Microsoft Reader.

But at least Gibson, for one, has now acknowledged Microsoft's achievement. Although the 1970s Apple work also involved pixel manipulation, it was intended to enable TVs, which have relatively poor resolution, to serve as computer monitors. Now that Microsoft has described the specifics of its technology, Gibson is a believer, calling the ClearType work "beautiful, scholarly, comprehensive and brilliant." **—Don Barker**



Pathogen-detecting cells glow in a serpentine chamber inside a glass Canary chip.

COURTESY OF MIT'S LINCOLN LABORATORY

Sensitive Cells

BIOTECH | Detecting the virus that causes foot-and-mouth disease typically requires hours and a trip to the lab—hardly feasible when testing millions of animals or travelers' shoes. Now engineers at MIT's Lincoln Laboratory are developing a portable sensor to spot the virus in seconds.

The core of the sensor, dubbed Canary, is a dime-sized glass chip that can detect tiny amounts of the virus from a raw sample of blood, saliva or even air, says inventor Todd Rider. Rider says it is the first pathogen detector to use white blood cells, which are naturally sensitive to viruses and bacteria. The researchers inserted two genes into white blood cells from mice. The first gene produces an antibody on the cell's surface that binds only to the foot-and-mouth virus. When that binding occurs, a second inserted jellyfish gene makes the cells glow.

When the Lincoln Laboratory group tested Canary's speed against a U.S. strain of the foot-and-mouth virus, the sensor produced results in 25 seconds. Now, the researchers are genetically engineering cells to detect the European strain, a project they expect to complete by early summer. The U.S. Department of Agriculture is exploring the idea of using the device at airports and border stations.

Researchers have also engineered the device to detect several potential biological warfare agents; in theory, says Rider, it could be designed to sense any live pathogen. "You could walk into the doctor's office, cough on something and get an instant diagnosis." —David Talbot

End of an Era?

Bush to reevaluate federal dollars for high-tech program

POLICY | As President George W. Bush and Congress battled over tax cuts, an element of the president's budget that some believe could have a much longer-term impact on America's economic health went largely unnoticed. Bush proposed to stop funding a landmark federal effort to help risky—and potentially lucrative—technologies out of the lab and into the marketplace: the National Institute of Standards and Technology's $200-million-per-year Advanced Technology Program.

Created in the late 1980s, the program seeks to ensure the United States' high-tech preeminence by funding development of cutting-edge technologies in corporate research labs. One notable success is the commercialization of DNA chips, which promise to revolutionize medical research and diagnosis. But now Bush has proposed suspending the program's funding for the next two years (though outstanding grants would be honored) while the U.S. Department of Commerce, which oversees NIST, reviews its economic and technical impact. The president's action appears to mark a dramatic turn away from federal support for the development of next-generation technology. While the GOP-led Congress fought to kill the program throughout the late 1990s, this is the first time the White House has appeared similarly disposed.

James McGroddy, former head of IBM research, helped start the program but feels its time has passed. "I was a big promoter of it 10 years ago because it was before the big venture capital explosion," McGroddy says. "I thought there were a lot of good ideas then that needed help to get over the chasm. That's not the environment we've been in for the last four or five years." In addition, though the program maintains its own economic assessment office, McGroddy questions whether there has been any comprehensive assessment of the program's economic impact.

Program proponents, however, call the president's move outrageous. Johns Hopkins economist Maryann Feldman, one of the outside experts who has conducted studies for the assessment office, says the Advanced Technology Program is "probably one of the most studied programs in government." Former NIST director Lewis Branscomb says, "The radical innovations that create both new markets and new technology are the toughest to bring off, but if you do bring them off successfully, the returns can be hundreds of times what the investment was. That's what [the program] tries to do."

And some, pointing to the proliferation of high-tech competitors overseas, see a danger in compromising the program's future. "Standing down while you reassess the program, that's two years of opportunities that aren't met," says Arden Bement, the head of Purdue University's nuclear engineering department and chair of the program's advisory committee. Bement notes that key program staff are likely to leave in the interim, leading to the loss of three to five years of program effectiveness; this could kill the program more efficiently than any direct political challenge.

If it does, it would mean an end to, arguably, one of the most successful technology collaborations of its time between government and industry. **—Erika Jonietz**

1988

New legislation creates the Advanced Technology Program, or ATP

1990

The Bush administration funds ATP for the first time at $10 million

1993

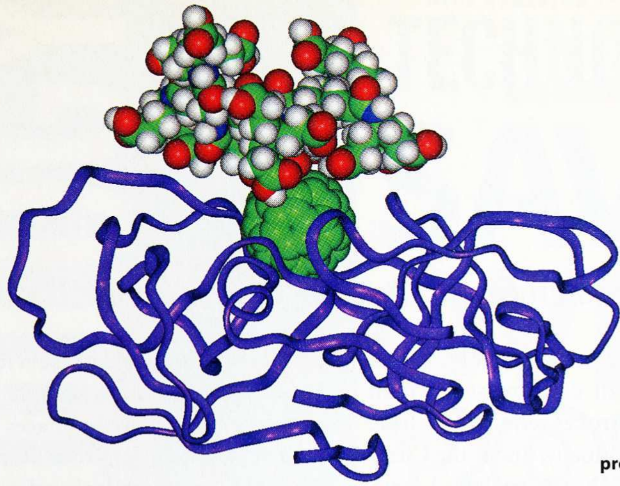
Clinton and Gore pledge to raise ATP funding to $1 billion, but fail to do so

1995

The incoming Republican Congress vows to eliminate "corporate welfare," including the ATP

2001

The new Bush administration proposes suspending ATP funding



COURTESY OF AUSTIN N. KIRSCHNER

C Sixty's anti-AIDS drug (red, white and green) blocks a viral protein (purple) in this computer model.

Buckyball Cures

A first generation of fullerene-based drugs is on the way

MEDICINE | In 1985 chemists discovered a soccer-ball-shaped molecule made of 60 carbon atoms and called it buckminsterfullerene—buckyball for short. Researchers have imagined using the molecule for everything from rocket fuels to lubricants, but real-world applications have yet to materialize.

That could soon change. Toronto-based C Sixty plans to start clinical testing of three fullerene-based drugs in the next year and a half. Coordinating the efforts of a dozen university researchers worldwide, C Sixty is developing drugs for the treatment of AIDS, Parkinson's disease, Lou Gehrig's disease, osteoporosis and cancer. "I think their chances are extremely good. The arguments for the success of these things are really quite stunning," says Rice University chemist and C Sixty scientific advisor Richard Smalley, who shared the 1996 Nobel Prize for his codiscovery of fullerenes.

About one nanometer in diameter, buckyballs are the perfect size to interact with DNA and proteins. And chemists can attach different chemical groups to the carbon scaffold, making drugs with multiple functions. New York University chemist Stephen Wilson, who developed the techniques that make this possible, calls buckyballs "molecular pincushions."

Fullerene drugs could also be exceptionally nontoxic. A fullerene-based version of an AIDS drug, for one, appears to be much less toxic than existing treatments. And it has another startling quality: it works against every drug-resistant HIV strain it has been tested on. Because the drug could fill an important growing niche in AIDS treatment, C Sixty plans to request "fast track" status from the U.S. Food and Drug Administration to help speed the drug to market. Fast-tracked drugs can reach pharmacies 18 months to two years from the start of testing.

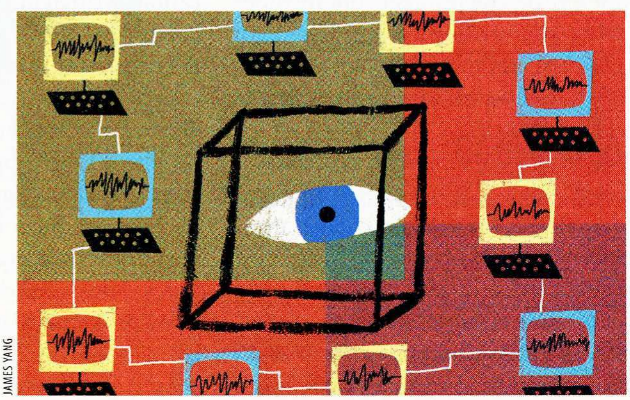
C Sixty is not without competitors, though. Fullerene International, a joint venture of Japanese conglomerate Mitsubishi and two Arizona-based startups, says it could begin testing buckyball-based drugs for cancer and AIDS by the end of the year. —**Erika Jonietz**

Continental Drive

INTERNET | **Most personal computers spend more time idle than active, so researchers are harnessing their latent processing power with "distributed computing." In this model, a computer connected to the Internet performs a task and then sends the result back to a central server for analysis *(see "Five Patents to Watch: Collective Computing," TR May 2001)*. It's an extremely powerful way to, say, sort through vast amounts of information looking for signs of alien life. But distributed strategies can't handle complex calculations, which require teamwork: each PC must crunch its own data, swap results with the others and repeat the process hundreds or thousands of times. All those computers talking at once slows the calculations—and the Internet—to a crawl.**

A system from Ottawa, Canada-based Internet research consortium Canarie could make the interactions between computers up to 20 times faster, expanding the scope of distributed computing. Project director Bill St. Arnaud has dubbed the system a "wavelength disk drive" because the exchanged data is stored in wavelengths of light circling in a fiber-optic network. Computers on the network can perform calculations and "write" the data to an assigned wavelength. They then "read" other processors' results from the light stream, repeating the process until the calculation is done.

This spring Canarie installed the software for the system on computers in its pan-Canadian network. St. Arnaud expects to test the first application this month: a model to predict the progression of forest fires. In a pinch, local firefighting teams can jump on Canarie's network, punch in their scenario and get a quick answer on where the blaze is headed and where they should focus their resources. "Most small communities in Canada are unlikely to have a supercomputer sitting around in the anticipation of this kind of emergency," says St. Arnaud. —Peter Fairley



JAMES YANG

Apps on the Fly

"Application streaming" will put complicated software in the palm of your hand

WIRELESS | For years the infotech industry has been predicting that wireless handheld devices would soon be as versatile as desktop computers. But the best handhelds on the market still don't come with enough memory to store the average Web browser, let alone Microsoft Office.

Fortunately, they may not have to. A technique called "application streaming" could allow Palm Pilots and cell phones connected to wireless networks to run large applications without storing the software locally. It's an updated version of the old mainframe network design, with programs residing on a central server, accessed from "dumb terminals" with very little computational power of their own. A handful of firms already market the technology for desktop computer networks and are working on versions for handheld devices, which they hope wireless service providers will adopt within a year. The results could include anything from writing a grocery list on a cell phone to editing an Excel spreadsheet on a Palm Pilot—and sending it off as an e-mail attachment.

COURTESY OF PALM

The technique can work in a couple different ways. Citrix Systems of Fort Lauderdale, FL, for instance, saddles network servers with all of an application's computational work, so that, according to senior product manager Steve Piper, "only the screen image is compressed and sent down to the client device," and "only clicks and keystrokes are sent back up." But even though compressed screen images and keystrokes require very little bandwidth individually, under the Citrix system they still shuttle back and forth almost constantly; it will take a pretty powerful bank of servers to keep up.

The competing approach is to break applications down into component parts and send users only the components they need at a given time. Of course, it isn't easy to figure out which components those are. Palo Alto, CA-based AppStream attempts to predict users' needs on the basis of past decisions; while Nortel Networks Application Management Solutions of Chelmsford, MA, hopes that, by breaking applications into small enough chunks, they'll be able to "see what the running application asks for and provide it on demand," says vice president of marketing Jon Friedman.

The companies also differ in the kinds of software they can stream. AppStream, for instance, has concentrated on applications written in the Java programming language—which is quickly becoming the dominant format for wireless applications in Japan. According to vice president of wireless business development Gerald Wluka, AppStream is pursuing several licensing agreements and should have its products installed on wireless network servers in about a year. In addition to Java-based chat, e-mail and videogame programs like those already popular in Japan, the AppStream technology should provide cell-phone users with continuous networked services—like scrolling sports scores or stock prices—and richer interactive interfaces for shopping or searching databases over the Web.

Wireless-Application-Streaming Firms

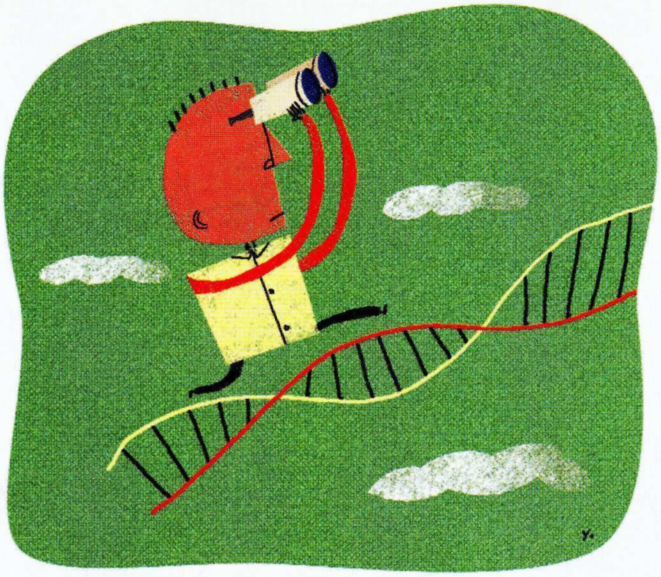
COMPANY	LOCATION	STREAMING TECHNOLOGY
AppStream	Palo Alto, CA	Application segments delivered according to predictive user profile
Citrix Systems	Ft. Lauderdale, FL	Server-side computing and downloaded screen images
Nortel Networks Application Management Solutions	Chelmsford, MA	Application segments delivered on demand

Nortel, on the other hand, is focusing on Windows-based software. According to Friedman, the company expects to release products designed for Windows CE—the Windows operating system for wireless devices—by the end of the year. Although the Nortel system could, in principle, work with any Windows application, Friedman anticipates that "providers will want to rewrite their programs" to accommodate the memory and bandwidth constraints of wireless networks.

As for Citrix, its technology requires that users load their handhelds with a program that funnels screen images down from the server. Piper says that program currently "supports dozens of handheld devices." At the beginning of this year, several companies in the United States and Europe began using the Citrix system to stream applications to personal digital assistants over local-area networks; and in March, Motorola signed a licensing agreement to incorporate the Citrix technology into its handheld devices.

To some extent, the different approaches are based on different market expectations. AppStream's Wluka envisions that, when you turn on your Java-enabled cell phone, you'll see a menu of different features that come with your wireless service package. Some, which you use frequently, will be stored locally; others will be stored on a network server—but you'll never know the difference. Citrix, on the other hand, promotes its technology as providing "wireless computing users with access to the same rich, full-featured applications they work with at the office."

The ability to do office work anywhere you can carry a Palm Pilot? Sounds like paradise. —**Larry Hardesty**



JAMES YANG

Sequence Sense

GENOMICS | When the U.S. Department of Energy helped initiate the Human Genome Project in the late 1980s, it reasoned that knowing the entire sequence of human DNA would help illuminate radiation's effects on the body—one of the agency's mandates. Just over a decade later, the completion of the Human Genome Project is transforming medicine and biology. Now the agency is proposing another ambitious program, "Genomes to Life," that it believes will aid other DOE missions: bioremediation, or neutralizing toxic waste with microbes or plants, and the production of clean energy using biological processes.

While biologists have sequenced the entire genome in humans and many other species, the DOE's proposed program addresses some of the basic questions researchers believe must be answered before this information can be translated into a cleaner environment, healthier food or better medicines. The program has four main goals: identifying all the complexes of proteins, or "molecular machines," that carry out cells' functions; mapping the complicated networks of molecules that control the activity of genes; using gene sequencing to understand how communities of microbes work together; and building the computing infrastructure needed to explore such information-rich questions. Aristides Patrinos, an associate director at the DOE, says the program was crafted to draw on resources, particularly in computing, that are unique to the agency.

Of course, the Energy Department is not the only group seeking to take advantage of the vast amounts of new genomic information. But Caltech biologist Barbara Wold, who helped craft "Genomes to Life," says the program would complement the efforts of such institutions as the National Science Foundation and the National Institutes of Health. Wold estimates the 10-year program would initially cost \$50 million per year, ramping up to an annual \$200 million. Says Wold, "The science is important and it's a wonderful way to leverage special resources and current [agency] capabilities."

—Rebecca Zacks

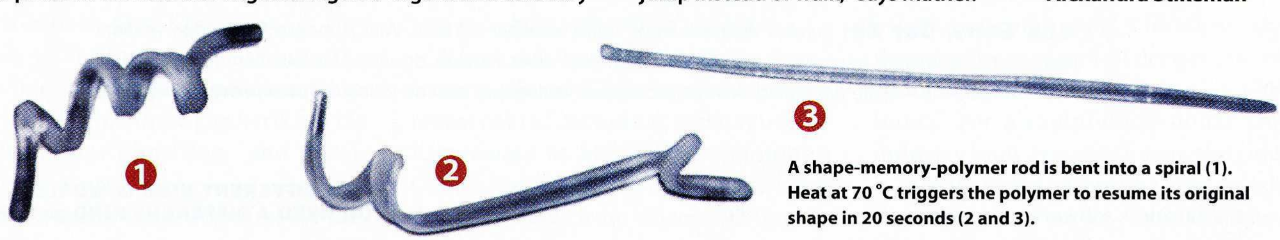
Total Recall

MATERIALS | Shape memory plastics are about as close as materials scientists get to doing magic. Bend and twist them all you want, but at the right temperature they'll bounce back to their original shapes. Now, for the first time, researchers have made shape memory polymers that are both compatible with the body and biodegradable—a potential breakthrough in the development of implantable therapeutic devices.

"You can envision a whole range of minimally invasive surgical products that you could insert through a small hole in the body and have snap into a desired shape," says MIT bioengineer Robert Langer, who helped develop the new material with Andreas Lendlein, a chemist at the German Wool Research Institute in Aachen, Germany. Lendlein and his team made the material from two biocompatible polymers; tweaking the ratio of the two sets the temperature at which the material will change shape. To commercialize the new polymer, Lendlein and Langer cofounded mnemoScience in Aachen, which plans to produce scaffolds for engineering new organs and coronary stents, the mesh tubes used to prop open blocked arteries. Such stents could be compressed and fed through a tiny hole in the body into a blocked artery. There, the body's warmth would trigger the polymer's expansion into its original shape. And rather than requiring a second surgery for removal, the polymer would gradually dissolve in the body over time.

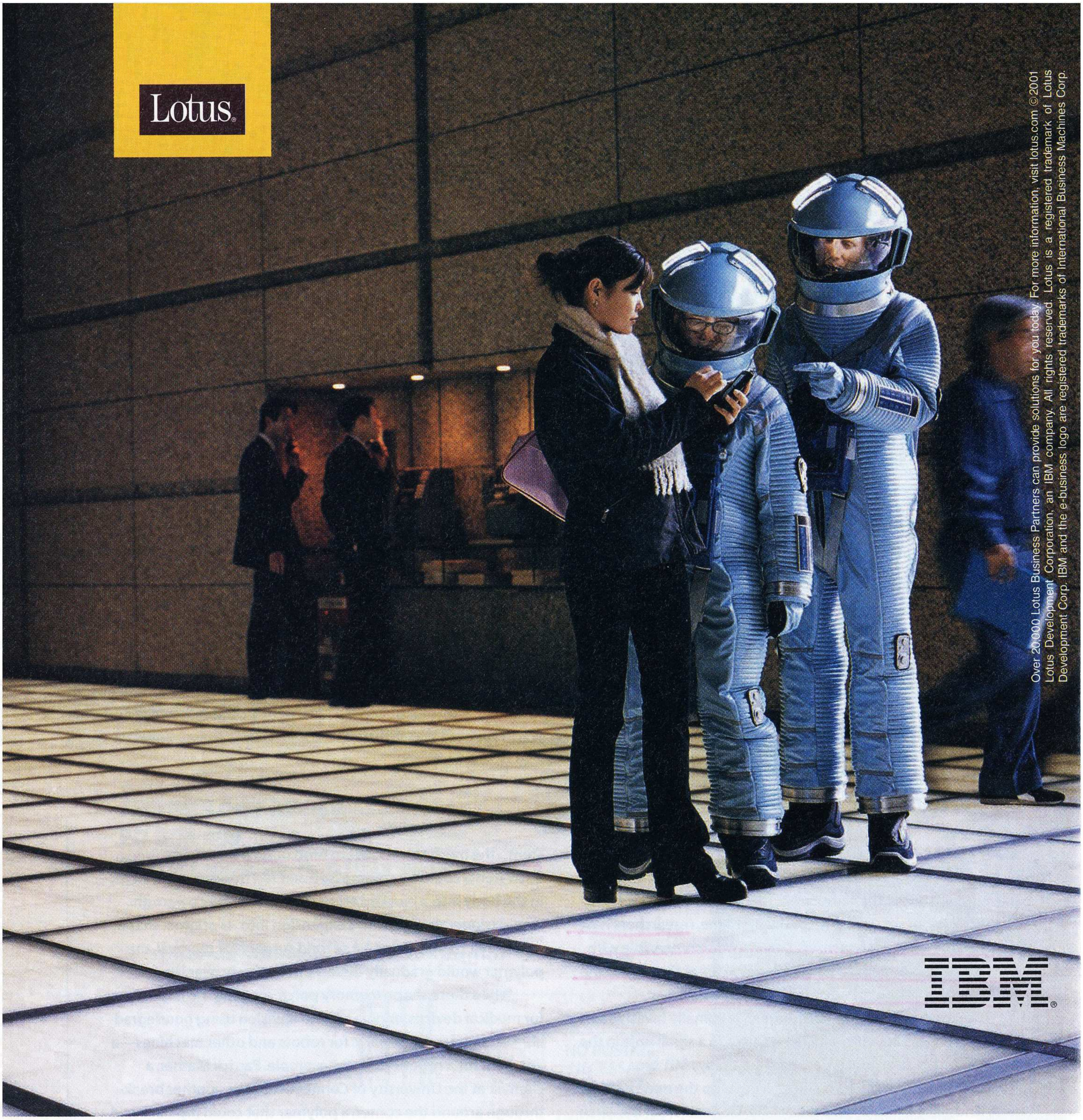
While these shape memory polymers could be important for medical devices, engineers also envision using nondegradable versions to make parts for robots and other machines—a ligament for a robotic limb, for example. Patrick Mather, a chemist at the University of Connecticut, sees another breakthrough around the corner: a polymer that could flip back and forth between two shapes at different temperatures, without having to be manually reshaped after every cycle. Engineers have already made these reversible shape memory materials with metal alloys, but they can only bend so much. "But, with a reversible shape memory polymer, we could make the robot jump instead of walk," says Mather.

—Alexandra Stikeman



COURTESY OF ANDREAS LENDLEIN

A shape-memory-polymer rod is bent into a spiral (1). Heat at 70 °C triggers the polymer to resume its original shape in 20 seconds (2 and 3).



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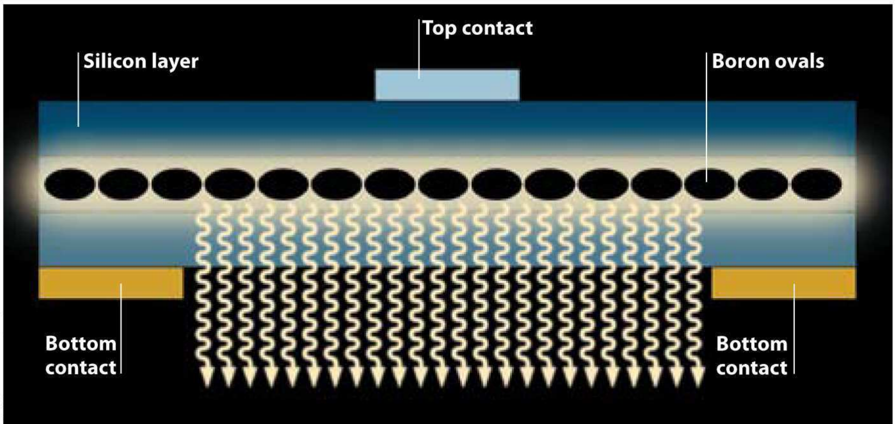
UPSTREAM

SPOTLIGHT ON A HOT TECHNOLOGY TO WATCH



SOURCE: KEVIN HOMEWOOD/UNIVERSITY OF SURREY

In the version of the silicon light-emitting diode made by researchers at the University of Surrey, boron implants (black ovals) are used to locally change the electronic behavior of the silicon. In response to an applied voltage, infrared light is emitted through the window between the bottom contacts.

Silicon Lasers

Faster chips require built-in optics

Silicon microchips, the thumbnail-sized microprocessors that constitute the brains of a PC, are heading for a disaster created by their own remarkable success. As chips get faster, the electrons that carry messages through the tiny metal wires within the integrated circuit are having a hard time keeping up.

One place where this looming problem is particularly acute is in the ultrafast clocks used to pace computation. Roughly speaking, faster clocks mean faster computing; microprocessors now run at clock rates over one gigahertz (a billion pulses per second) and are getting faster all the time. Soon, says Lionel Kimerling, director of MIT's Microphotonics Center, electrons moving through metal wires will simply be too slow to keep pace. "Assume that somewhere in the future is a 10-gigahertz clock. It's impossible to distribute that kind of signal electrically," he explains. The solution, says Kimerling, is tiny pulsed lasers that can distribute the clock signals through the processor chip. "Intel thinks that three gigahertz is a big problem," says Kimerling, "and that is about two years away."

Over a dozen research groups are racing to develop miniature optical devices capable of being integrated right into the silicon chip. It would be a kind of optical network to ferry data around the microprocessor, boosting its capabilities in the same way fiber optics have transformed telecommunications. But there's a problem: silicon is a lousy light emitter.

Silicon's curse is that it is, in the jargon of physicists, an "indirect-bandgap" material. Other semiconductor materials are good light emitters because when their electrons are kicked up to a higher energy by a current, the electrons can drop right down again and fire off a photon in the process. Pump a lot of electrons rapidly into a higher energy state, and you can make a laser. This is how the semiconductor laser used in a DVD player works, for example. But the laws of physics say that the electrons in silicon cannot travel directly back to a lower state. As a result, the electron usually gives up its energy as heat rather than as light.

There are two strategies for overcoming silicon's "light" problem. Some researchers, including colleagues of Kimerling's at MIT's Microphotonics Center, are developing light emitters and detectors made from silicon's siblings—semiconductors like gallium arsenide—that can be grafted directly onto silicon chips. Other groups have found ways to get silicon itself to emit the desired light.

In 1996, Philippe Fauchet and his colleagues at the University of Rochester reported a light-emitting diode made from silicon. The device had an important characteristic: an electric current rather than another laser or light source could be used to trigger the light emission. But, says Fauchet, the efficiency of the device in emitting light is too low to interest chip makers. "In these light-emitting devices, the power efficiency is around 0.1 percent," he explains. "But the minimum acceptable standard in the industry is one percent before they will talk to you."

Silicon's light-emitting powers got a boost last November when Lorenzo Pavesi at the University of Trento in Italy found that silicon nanoparticles could amplify light. What made this exciting is that amplification is the first step toward making a silicon laser. "With a laser, it's a whole new ballgame," says Fauchet. "Some of the efficiency issues go away." The nanocrystals, however, have to be stimulated by a laser rather than electric current.

Then in March a group led by Kevin Homewood at England's University of Surrey discovered another way to get silicon to glow on its own. "Our approach uses absolutely standard silicon technology," says Homewood. These silicon-based light-emitting diodes are not optimized for efficiency, Homewood acknowledges, but he says they are only a factor of three away from conventional light-emitting diodes. Homewood's next step is to try to get laser action. "I certainly don't think the physics is against us," he says.

Despite these tantalizing hints of success, Fauchet says research in light-emitting silicon faces some tough challenges. "The trouble with all these devices, including ours, is the low efficiency," he says. "As research, it's very interesting, but Intel is not jumping yet."

Still, the future of silicon microphotonics is bright. Whether they're silicon lasers or light emitters made from some other semiconductor, Kimerling says the integration of optical devices into silicon chips "is the next big step" in photonics. For a multibillion-dollar chip industry built around silicon, the clock is rapidly ticking toward a way to take that step. —**David Voss**

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Looting the Library

A FEW YEARS AGO, I WAS walking down the street in one of Manila's poorer neighborhoods when I came upon a gaping hole where a sewer grate used to be. It was an experience doubtless familiar to many who have traveled in the Third World: someone had presumably looted a humble—but essential—piece of the city's infrastructure. It brought home to me not only what a robust infrastructure we take for granted in the West, but also how easily it can erode.

I am reminded of that missing sewer grate by an all-out battle brewing here in the United States—only the gaping hole we're threatened with is in the stacks of our public libraries. And in this case it's the publishing industry doing the looting. As we plunge into the digital realm, the nation's 16,000 public libraries are striving to uphold their tradition as protectors of public access to new books and articles. But publishers, in an increasingly bald, frontal assault on the library's mission, have something very different in mind: a pay-per-use model for information content that will largely shut libraries out.

The battle is being waged on many fronts, from legislative initiatives and lawsuits to the publishing industry's unilateral pursuit of copy-protection technologies that will keep users—including libraries—from sharing digital content. One of the loudest and most shameful voices in the debate is that of Patricia Schroeder, president and CEO of the Association of American Publishers. The former Colorado congresswoman enjoys a distinguished 12-term record of championing women's rights and sponsoring legislation such as the Family Medical Leave Act. But in her latest incarnation as a front for the publishing industry, Schroeder has been quoted as saying that publishers have to "learn to push back" against libraries, which she portrays as an organized band of pirates!

At her most hyperbolic, Schroeder has implied that if libraries let people borrow electronic versions of books and journal articles, there will be "no copyright left."

There's no question that publishers need to control content in cyberspace. But to hear Schroeder tell it, legions of librarygoers are primed to topple the publishing industry. She conjures up visions of readers pirating electronic copies of the latest works by E. O. Wilson and Maya Angelou faster than Napster users swapped songs by Metallica and Britney Spears. Her industry's answer to this far-fetched scenario is a preemptive campaign to make people pay for any and all access to published works—even those borrowed from libraries.

Just look at the fight over the back issues of journals and magazines. Following a legal precept called the "first-sale doctrine," once libraries have purchased a given copy of a magazine or book, they have been free to archive it and make it available to their patrons. But now, when libraries subscribe to a journal online, their access to back issues is at the vendor's discretion. Since publishers now see libraries as a threat to their ability to profit from this body of published work, they are trying to overturn the first-sale doctrine. What's more, journals and magazines are just a piece of a larger picture; both sides know that any new rules will likely govern access to e-books as well.

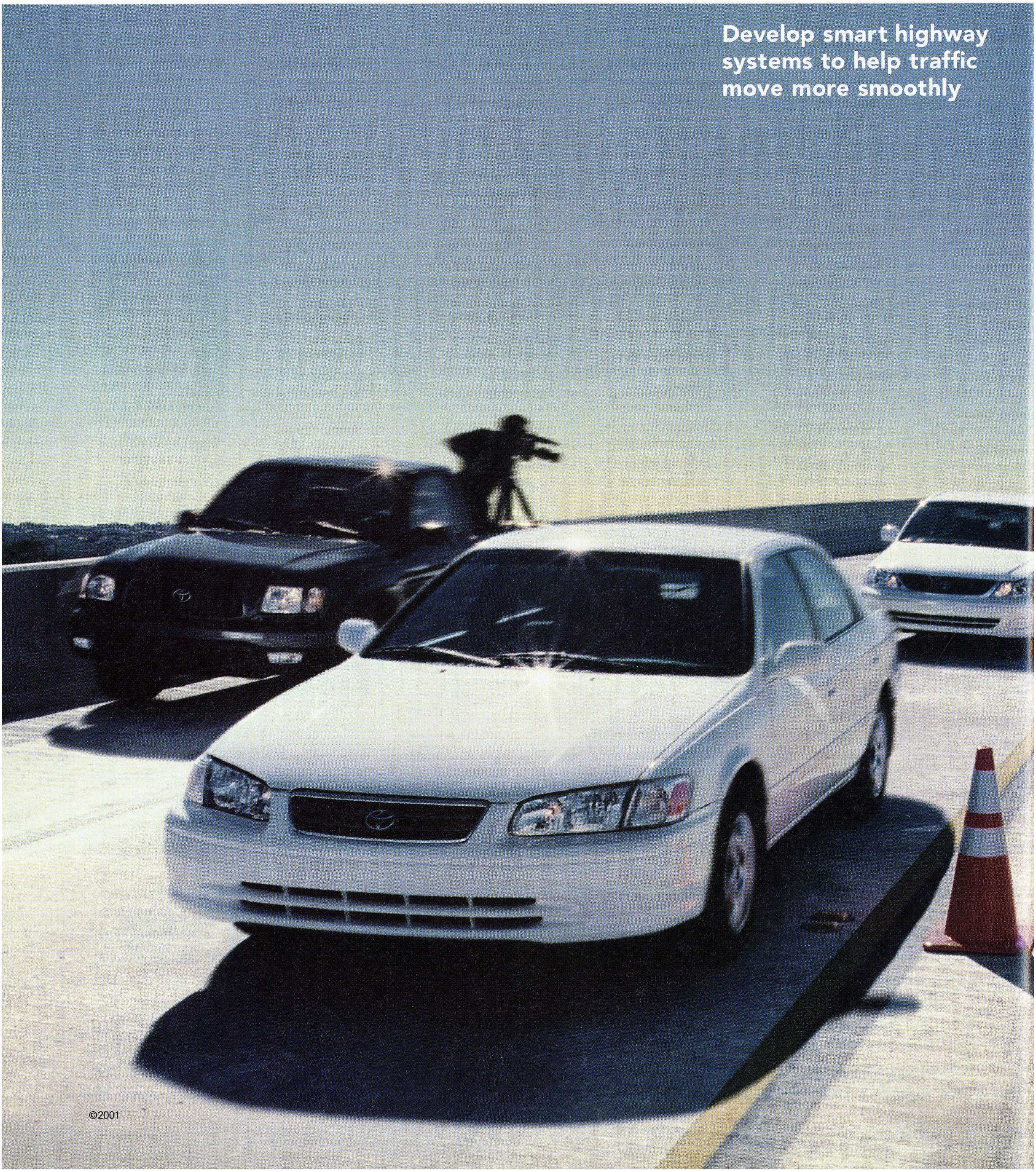
Perhaps even more troubling is the publishing industry's wholesale attack on the "fair use" provisions of copyright law, whereby parts of works can be legally quoted or copied for noncommercial and educational purposes. Take, for example, a scheme spelled out recently by Peter Chernin, president and chief operating officer of Rupert Murdoch's News Corporation, which counts HarperCollins Publishers among its vast media holdings. Chernin is calling for legislation that, according to *Publishers Weekly,* "guarantees publishers' control of not only the integrity of an original work, but of the extent and duration of users' access to that work, the availability of data about the work and restrictions on forwarding the work to others." Put in plain English, Chernin is advocating a world that precludes the possibility of libraries as we know them, save perhaps as repositories for the fast-aging hard copies they already hold.

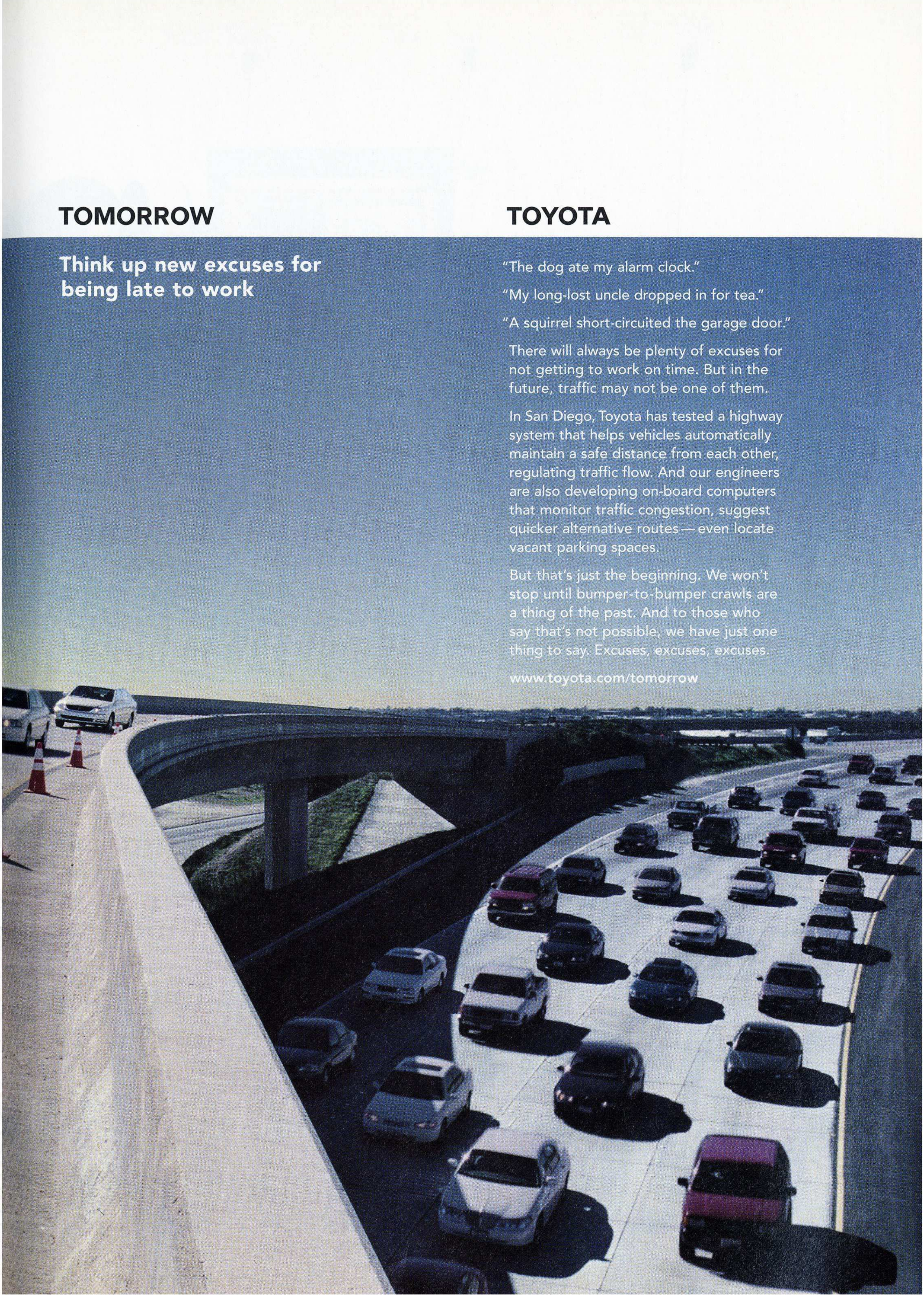
Pat Schroeder and the publishing industry are trying to paint libraries as organized pirates. For shame.

We will undoubtedly hear much more from Schroeder and Chernin as this complex battle is joined. However, the answer is emphatically not to abandon the core mission of the library but to reinterpret it for these times. Whatever systems are developed to control the exchange of published work in the digital realm, we need to insist on provisions for the kind of public access that libraries have traditionally made possible. Too much is at stake to let the publishing industry undo the careful copyright balance we have all come to rely upon.

All of which brings me back to that Manila sewer grate. Just as residents there came to treat gaping holes in the street as a normal—even acceptable—condition, we could get used to a world without public libraries. But the absence of free and accessible information would leave a gaping hole in our "infostructure" and result in an impoverished world. It is a world we can—and should—resist. ◊

TODAY


Develop smart highway
systems to help traffic
move more smoothly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Surging Internet growth has put pressure on telecom networks to keep up. Their most advanced R&D is going toward expanding the capacity of the long-haul cables that cross continents and dive under oceans.

By Neil Savage
Photographs by Beth Perkins

BUILDING A BETTER BACKBONE

Lumbar specialist: Roe Hemenway of Corning in front of equipment for testing the effects of new components on fiber-optic transmission.

On a giant screen at the Corning Museum of Glass in upstate New York, video images flash by—news footage of a war, an inauguration, a spaceshot, a game show—along with real-time projections of museumgoers staring up in wonder. The source of all these images? A strand of glass, thinner than a human hair, yet wide enough to carry more information than three million copper wires, the technology it replaced. Cor-ning is justified in showing off its invention: optical-fiber technology ranks as one of the technological miracles of the 20th century.

Too bad we're in constant need of new miracles to keep up with the voracious network demands that *this* century is placing on these thin glass fibers. Fiber optics is, after all, a pre-Web technology; and much of the fiber that carries—in addition to telephone conversations—today's e-mail messages, music downloads and video streams was installed before most people were even aware of those media. What used to seem like a shameless waste of capacity now seems woefully inadequate. Our appetite for bandwidth is growing at an exponential rate, with no sign of slowing. Tracey Vanik, technical director at telecommunications consulting firm RHK, compares the Internet to *Star Trek*'s voracious Borg: "Whatever bandwidth is made available, the Internet will swallow."

Optical fiber made by Corning, Lucent Technologies and other giant telecom suppliers is found throughout the telecommunications system, connecting us when we browse our favorite Web sites or place calls to Tokyo. But much of the cutting-edge research being done today on fiber optics goes into improving the capacity of the system's "backbone": the fattest of the fat data pipes, which whip data across continents and connect urban centers.

"Backbone" is a convenient metaphor—but it gives too neat a picture. A vertebrate organism has a single backbone, but the telecom system doesn't; no single company owns these high-capacity interurban cables, and no one organization makes sure they are up to the challenge of meeting worldwide bandwidth demands. In some cases telecommunications companies—the WorldComs and Sprints and AT&Ts of the world—will seek to cover high-traffic routes with their own cables, laying spaghetti-like strands parallel to one another along highway and railroad rights-of-way, linking metropolitan loops across continents and oceans. In other cases, carriers lease optical-fiber cables from other carriers; indeed, some carriers are solely in the business of leasing backbone capacity.

All carriers, though, are faced with the same challenge: how to stay ahead of the bandwidth demand curve. Research at Corning and elsewhere shows that every improvement in performance comes at a price; building a better backbone seems to be a question of choosing just the right trade-offs.

BEEFING UP OPTICS

The simplest solution for stiffening the backbone is simply to lay more cable. But that's also the most expensive alternative: as much as 40 percent of the cost of a fiber-optic system goes toward purchasing rights-of-way, getting permits and putting cable in the ground. (It's an old joke in telco companies that they'd gladly give up new technologies if someone would just show them how to dig a cheaper ditch.)

Two other ways to increase capacity avoid digging up the streets, relying instead on state-of-the-art equipment installed in the telephone offices where the fiber-optic strands terminate. Engineers can develop methods to increase the number of channels of information

One Carrier's Backbone

The telecommunications company Qwest is looking for ways to beef up its nationwide backbone—the routes that connect major cities.

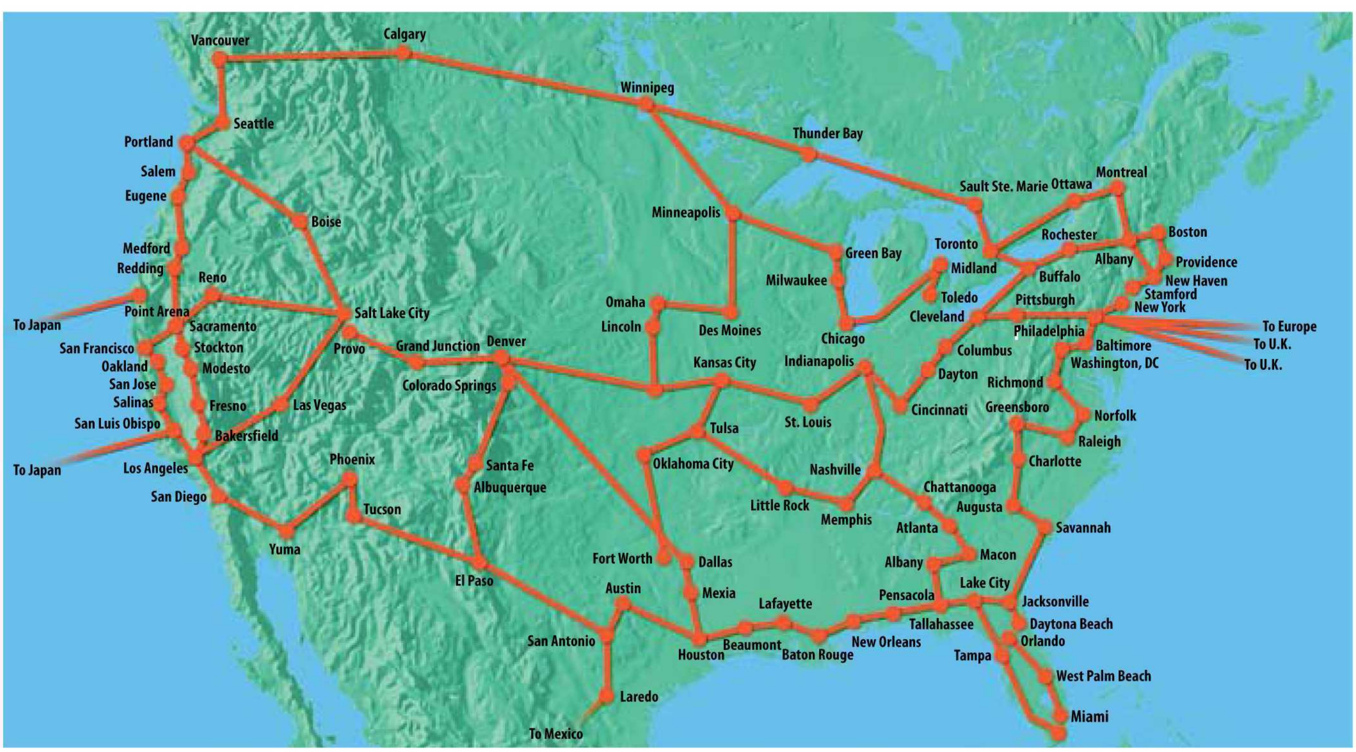


ILLUSTRATION: BETSY HAYES; SOURCE: QWEST COMMUNICATIONS

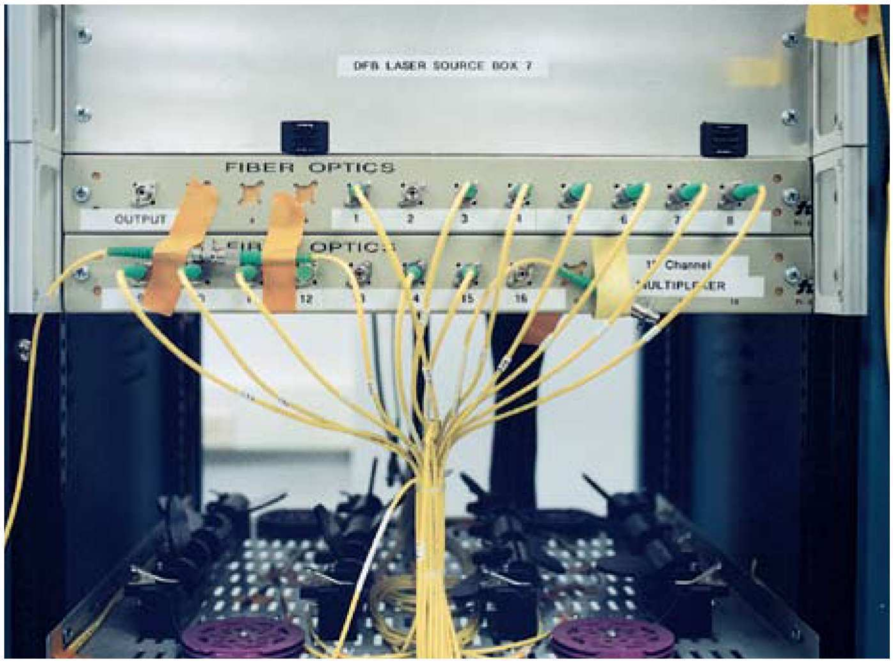
each fiber-optic strand can carry. Or they can develop ways to make the data travel faster along each channel.

Both approaches avoid the enormous cost of installing new lines. But each strategy is tricky, since making improvements in one area often causes problems in another. "There's a strong trade-off between distance and capacity," says Roe Hemenway, manager of network equipment research at Corning. "The further you go, the lower the capacity. We're being asked to put more capacity on the fiber, go longer distances, and do it with even higher quality."

Hemenway works in the laboratory at Corning's Sullivan Park Research and Development Facility in upstate New York, where shelves hold rows of metal boxes, each one a laser that generates an infrared beam. The beams run through modulators and multiplexers, amplifiers and filters, traveling the same loop of fiber-optic cable over and over again to simulate distance, much like a digital race car on the information-superhighway version of a test track. At the end of the system a computer screen displays the number of errors produced during the run, and an oscilloscope shows graphically whether the signal came out sharp or blurry.

The setup allows Corning engineers to test how each component affects signal transmission, and what a change in one does to the system as a whole. This approach is critical to fiber-optic design, because whatever solution evolves to make fiber optics more efficient is likely to include a number of technologies, each of which might affect the others.

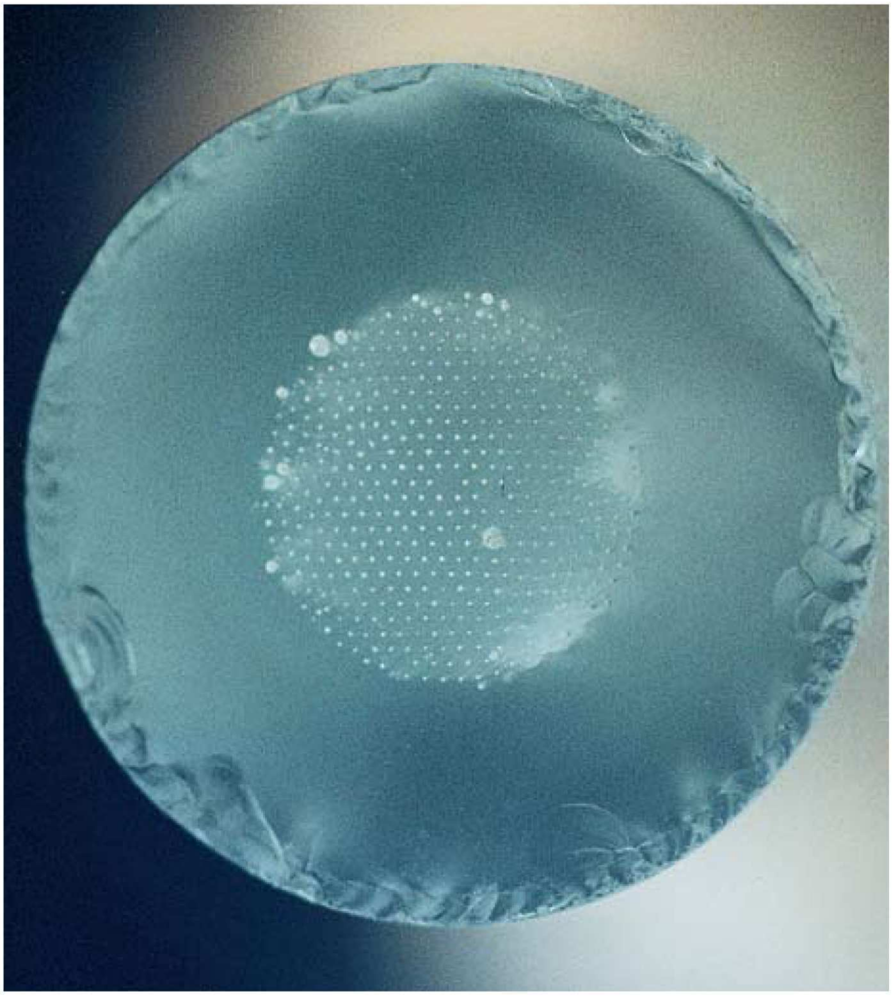
In the last six years, transmission speeds in the labs for the fastest fiber optics have quadrupled, and another fourfold increase is expected this year. The most pressing question is whether, given all the trade-offs, the current rate of improvement can be maintained. "I could give you a macho answer that we're going to continue to improve fiber, but quite frankly, I don't know," says Joseph Antos, technology director for fiber development at Corning. "Every new invention [to increase capacity] gets harder and harder."

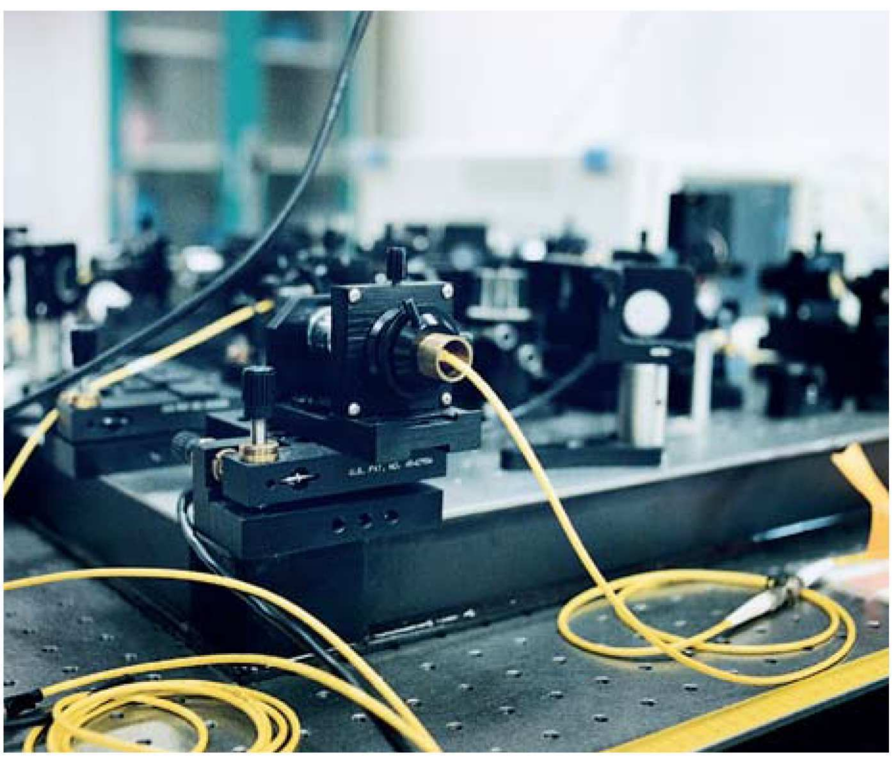


Over the wire: A single strand of the fiber-optic material stored on these spools (bottom) can carry the same amount of information as three-million-plus copper wires. Like a race car on a test track, signals travel round and round the same loop of fiber (top) in Corning's upstate-New-York lab to simulate the distances they must travel over the backbone.

MORE CHANNELS PER FIBER

Data travels along optical fiber through a series of light pulses from a laser, the offs and ons corresponding to the ones and





Shape of things to come: Dispersion-testing equipment (bottom) measures the shape of the optical signal; the further the signal travels, the more distorted it will become. A closer look (top) at the tip of a fiber-optic "preform," several millimeters across, before it is pulled like taffy to become a hair-thin fiber-optic strand.

zeroes of digital coding. Fiber-optic systems use the light spectrum that travels most efficiently through the glass, wavelengths between about 1,300 and 1,600 nanometers. Outside of these wavelengths light tends to be either absorbed and lost or stretched too far to make a usable signal. And of the available spectrum, most transmission takes place in what's called the "central band," between 1,530 and 1,565 nanometers.

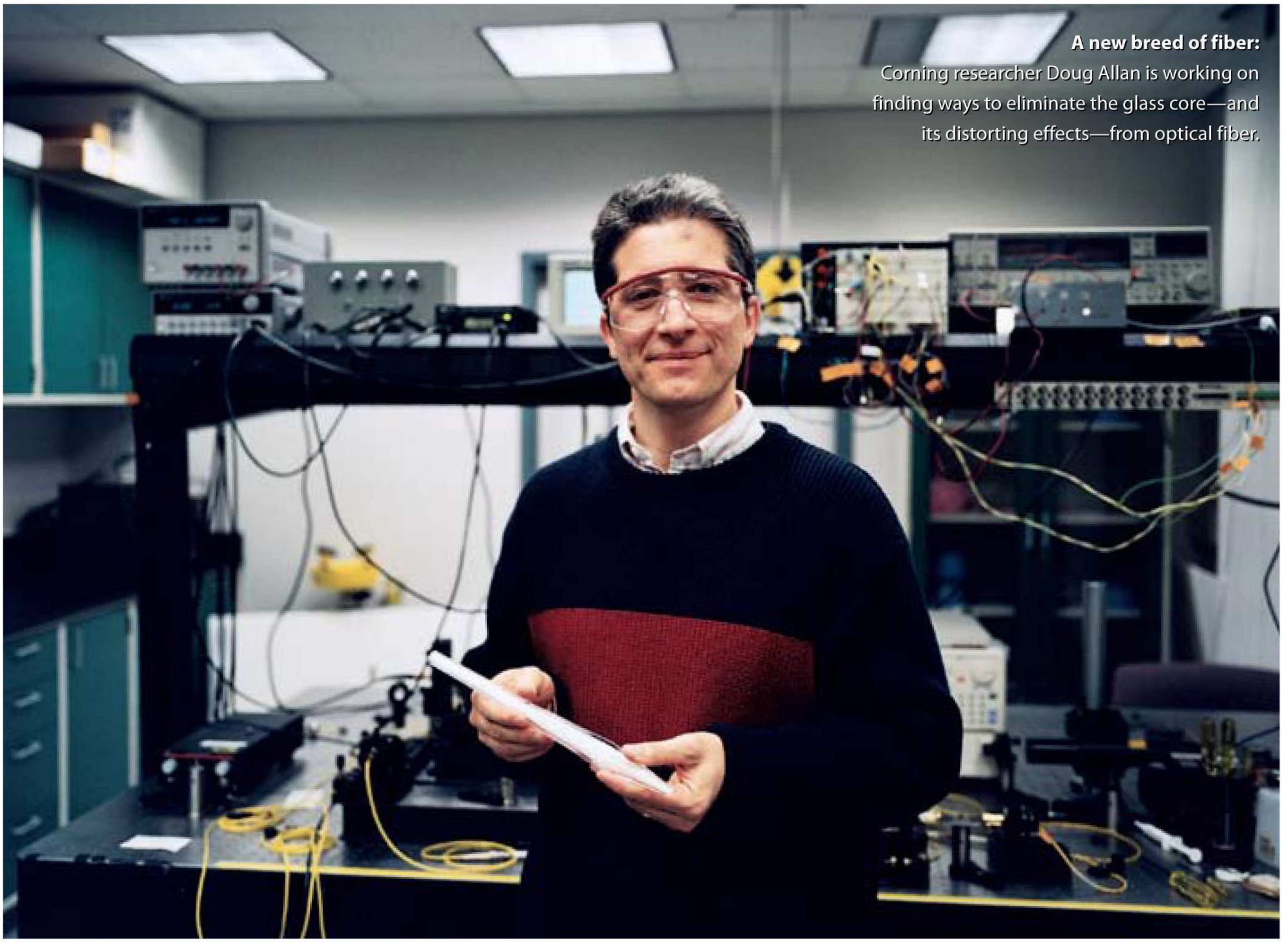
By breaking the signal into different wavelengths, as a prism separates the colors that make up white light, engineers can send more than one stream of light along a fiber at the same time. Early implementations divided the light into four or eight separate channels, with each fiber carrying about 10 gigabits—10 billion bits—per second. Today some systems can carry 80 channels in the central band, and are able to push more than a half-trillion bits per second down a single fiber.

But there's a limit to how many channels can be squeezed into the central band. Like closely spaced stations on your car radio, channels that get too close cause interference. On the radio, you might be listening to *All Things Considered* and suddenly get the Backstreet Boys—or static. The same thing happens with optical signals. To reduce interference, current state-of-the-art systems require a buffer zone of about 50 gigahertz (a measure of frequency of a billion cycles per second) between channels.

As a result of these constraints, the central band is now essentially full, and engineers are looking to add channels by moving out of the central portion of the spectrum and into new territory.

BREAKING NEW GROUND

In order to make new parts of the spectrum—outside the central band—usable, researchers must develop new versions of devices that help push signals along optical fibers. Take the amplifiers that help boost signals, which lose energy as they bounce back and forth between the walls of the core section of the fiber. To pump them back up, engineers might use devices known as erbium-doped-fiber amplifiers. These are essentially loops of fiber laced with the rare earth element erbium. A laser excites the erbium atoms, which transfer their energy to the optical signal passing through the amplifier, increasing



A new breed of fiber: Corning researcher Doug Allan is working on finding ways to eliminate the glass core—and its distorting effects—from optical fiber.

the distance it can travel. Without amplification, high-speed signals wouldn't travel far enough to be useful.

Recent developments make it possible for these amplifiers to work in the longer-wavelength region of 1,570 to 1,625 nanometers, adding a new chunk of spectrum from which to carve additional data channels. Lucent Technologies, for example, has released a system that squeezes 80 channels into the central band and exploits erbium amplifiers to add another 80 channels in the long-wavelength region, doubling the capacity of each fiber.

Every time a signal runs through an erbium amplifier, however, it picks up noise—elements that were not a part of the original signal. Over long-distance backbones where a signal needs to be boosted many times, fiber-optic systems must be strung with regenerators, devices that reconstruct signals that have traveled through so many amplifiers that they have degraded. Regenerators take a light signal, convert it to an electrical signal, and then produce a new light beam.

A new technique called Raman amplification *(see "Five Patents to Watch: Booster Shots,"* TR *May 2001)* will allow a signal to be amplified without introducing noise—doing away with the need for regenerators and potentially creating a new way for engineers to increase capacity. Unlike erbium amplifiers, which only work at certain wavelengths, Raman amplification holds the promise of making even more new channels available. A new company, Xtera, of Allen, TX, is hoping to take advantage of Raman amplification to enable the long-range transmission of shorter wavelengths of light than current optical networks can support. "It's kind of a new twist on using Raman techniques," says Joe Oravetz, Xtera's product manager, who unveiled the company's first new product at the Optical Fiber Communication Conference and Exhibit in March in Anaheim, CA.

But using the shorter-wavelength band is a decidedly long-term strategy, since it will require installation of new equipment at every point in the network. "Going into a new band, you have to replace all the components," says Vladimir Kozlov, an analyst at RHK. "You need new sources. You need new amplifiers. It could be very expensive."

SPEEDING UP BITS

An alternative to adding channels is to make the data stream in each channel flow faster. Just as the modems in people's homes have gotten faster, transmitters in the backbone have increased their ability to pump data, from 100 million bits per second a decade ago to a state-of-the-art 10 billion bits (10 gigabits) per second today.

While AT&T issued a press release announcing the first 10-gigabit-per-second coast-to-coast Internet protocol backbone in January, it's already old news: 40-gigabit-per-second systems have already been announced by Lucent Technologies, Fujitsu and NEC for sale later this year. The engineering feats involved in advances like these are tremendous: increasing the data rate required engineers to design lasers that can reliably flash on and off 40 billion times per second, and receivers that can pick out one

flash from the next, when they're coming at that overwhelming rate.

But the name of the game in the backbone remains trade-offs, and speeding up transmission rates causes new complications: putting more bits per second into a fiber requires more power, and at higher powers, the interference between channels increases. Also, at these remarkable rates, tiny flaws in the glass itself start to interfere with the flow of data.

Engineers going for speed must compensate for such effects by increasing the buffer zone of unused spectrum between channels: a 40-gigabit-per-second line speed, for example, may require buffers of 100 gigahertz between channels instead of 50 gigahertz. The math is still favorable: the fibers will deliver half the channels at four times the speed, doubling capacity.

The stakes involved in improving transmission rates in the backbone, however, are so great that for every obstacle, there are teams of engineers working to overcome it. Scientists at NEC America's Public Networks Group are working on a way to squeeze channels together, even at high speeds, by taking advantage of the fact that light is polarized. Imagine moving a jump rope rapidly up and down to make waves, which move up toward the ceiling and down toward the floor. Such waves would be "vertically polarized." Now start moving the jump rope from side to side, so the waves move toward the walls. Your jump rope has become horizontally polarized. The NEC approach divides a light beam into 160 channels, each 50 gigahertz apart, and gives neighboring channels different polarizations. Two channels with the same polarization are thus still 100 gigahertz apart. While channels next to one another are likely to interfere with one another when they have the same polarization, channels with different polarizations are not. Such an approach will boost total capacity per fiber to 6.4 trillion bits (6.4 terabits) per second and is projected to be available in two to three years.

And improvements continue in labs worldwide. In March, researchers from the French company Alcatel, which develops fiber and components for both land-based and undersea optical systems, announced they'd developed a system reaching 10.2 terabits per second. Also in March, researchers at NEC announced an experiment in which they tweaked amplifiers to get access to a wider wavelength band, increasing transmission rates to 10.9 terabits per second.

OR DIG A TRENCH

All of these technological developments, of course, face this challenge: how to continue to improve performance over lines that were typically designed, manufactured and installed many years earlier. The first fiber-optic lines in a public network were installed under downtown Chicago in 1977. Today, most of the world's long-distance traffic is carried by optical-fiber cables—more than 370 million kilometers of the stuff, all of it designed before today's breakthroughs in the labs. Eventually there will be no avoiding the need to dig a new trench.

The stakes involved in improving the backbone are high—and legions of engineers are attacking the problem.

Once the decision is made to lay new fiber, though, new possibilities to increase its capacity emerge. The fiber strands themselves have evolved to handle ever larger capacities. Today, the state-of-the-art is "nonzero-dispersion fiber," invented by Lucent Technologies and sold by both Lucent and Corning. This version of fiber widens the area through which a signal travels, giving it more room to spread and reducing overlap. "If you have a water pipe and you want to put more water down it, one of the ways to do that is to widen the area of the pipe, and that's essentially what [this technology] does," says Corning's Antos.

Next-generation optics technology may get rid of the glass altogether. Several research groups are working on building a fiber out of new materials known as "photonic-band-gap crystals" *(see "The Next Generation of Optical Fibers,"* TR *May 2001)*. Such crystals have an atomic structure that makes it physically impossible for light to pass through or be absorbed, so light striking the inside of a fiber would bounce back into the core. Doug Allen, a research associate at Cor-ning working on developing such a material, suggests that the core could be filled with air, or perhaps an inert gas. By eliminating glass and its distorting effects, he says, "you can send more wavelengths without worrying about them interfering with one another."

All these new developments have thrust research in the lab far beyond what's currently available in the ground. If the backbone were equipped only with developments being demonstrated in labs right now—able to carry 160 channels over each strand, at 40 gigabits per second—the bandwidth we currently use in a month could be carried over our networks in less than a second. That's when far-flung ideas start to get real, from holographic, 3-D videoconferences that mimic real life, to long-distance surgery, to instantaneous access to books stored at any library in the world.

What remains to be solved, though, is the economics of such a network: when will it be cost-effective to put these developments in place? In something as vast as the public communications network, even small upgrades take decades to be universally deployed. Theodore Vail, first president of AT&T, succeeded in building the world's first state-of-the-art public network only by getting Congress to declare his company a natural monopoly. That's not going to happen this time.

Raj Reddy, professor of computer science at Carnegie Mellon University and director of the High Speed Connectivity Consortium, a program funded by the U.S. Department of Defense, nevertheless remains optimistic that a very high-bandwidth network is inevitable—that one day we'll have always-on, all-you-can-eat bandwidth, as easily accessible as the phone system is today. "It's definitely going to happen in 30 years," he says. "[But] what do we have to do, and what do we have to spend, to do it in five?"

And that, in spite of the legions of fiber-optics engineers dedicated to discovering the technological miracles that will power our next-generation networks, is the question waiting to be answered. But given the remarkable spectrum of cutting-edge work being done on the backbone, it is undoubtedly there that capacity will continue to increase at the most rapid rate. ◊

A

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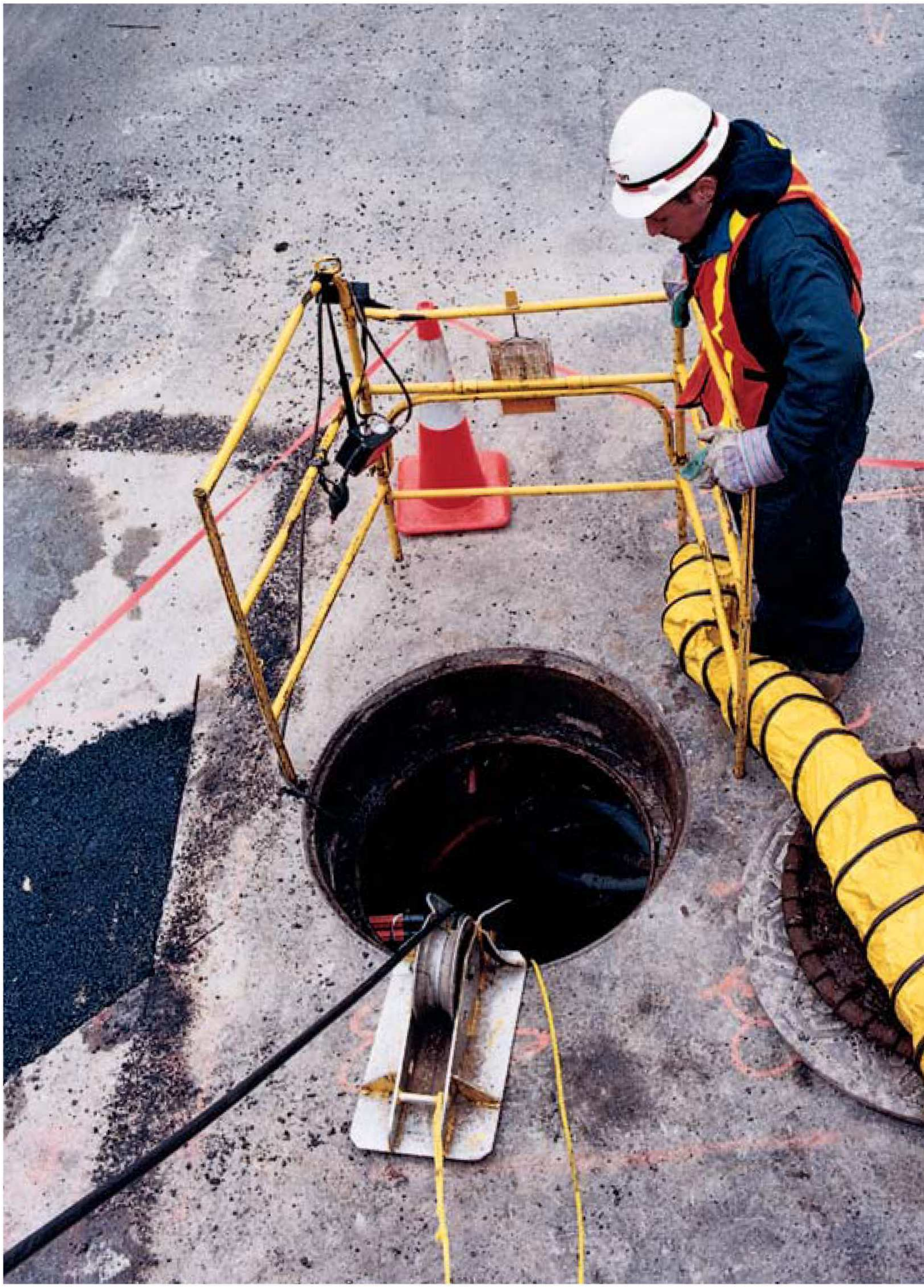
BREAKING THE METRO BOTTLENECK

The information racing across the country in huge fiber-optic pipes hits a snarl under city streets. New optical networking techniques are clearing the way. By Jeff Hecht

Photographs by Jan Staller

IN THE SO-CALLED BACKbone of the telecommunications system, the fat pipes that pour data across continents, the name of the game is raw speed *(see "Building a Better Backbone," p. 40)*. But the data racing through the telecom backbone can't fulfill its mission until it is shuttled through the "metropolitan loop," a complex network of cables and switches that delivers those bits to businesses, factories, schools and homes. It's there that the information gusher narrows to a relative trickle, because the metro loop is every bit as tangled as downtown rush-hour traffic. If the broadband revolution is ever to be a reality, the metropolitan bottleneck must be broken.

But that's a tall order. Upgrades in the metro loop have been far slower in coming than advances in the backbone. The reasons range from tougher cost constraints to urban bureaucracy to the presence of a patchwork telecom infrastructure dating back to the 1970s and '80s. But R&D aimed specifically at the metro loop is slowly pushing a variety of solutions out of the laboratory and under the streets. And if we really want broadband, those fixes had better work.



In the "metropolitan loop," the information gusher from telecom pipes slows to a relative trickle.

WEAK LINK

To grasp the scale of the bottleneck, consider the metro network's place in the telecom ecology. In the backbone, transmission speeds are measured in trillions of bits per second. On the user end, high-speed networks run at billions of bits per second (gigabits). But the metro systems that link these two high-speed networks poke along at mere millions of bits per second (megabits). "That's the bottleneck," laments Steve Schilling, presi-dent of access networks at Nortel Networks. And this metro-loop constriction isn't just a problem for the companies that run the networks. Regular folk experience it as trunk-line busy signals and stalled Web browsers.

If you're looking for a culprit here, don't finger the phone companies that run the metro loop. They planned prudently (at least, so they thought) for steady growth in voice communications, which at the time was their bread and butter. Then they, along with everyone else, were blindsided by the explosion of the Net. "Two to three years ago, we started running into capacity problems" in urban areas, says Stuart Elby, who heads development of Internet-connected networks at Verizon, the phone company serving New York and New England. Speeds of 2.5 gigabits per second, enough to handle heavy Net-generated traffic, are common only in the hearts of big cities like New York or Boston, where Verizon runs fiber-optic cable with 48 strands. More

The fiber down below: A Verizon worker puts high-capacity optical cable under the streets of New York City, near the United Nations headquarters.

typical metro-loop speeds range from 1.5 to 600 or so megabits per second.

And there's no letup in sight for the beleaguered metro operations. "More and more applications are emerging as you have more bandwidth," says Claude Romans, an analyst with the South San Francisco market research firm RHK. If digital television ever gets off the ground, for instance, it could gobble up huge chunks of bandwidth; it takes 1.5 gigabits per second to transmit a single, studio-quality high-definition video channel (although consumers will see only a compressed 20-megabit-per-second version). That kind of data onslaught will bring the metro loop to its knees without significant technological upgrades.

The current and future transmission slowdown afflicts both main components of the metro loop's hub-and-spoke structure *(see "Ring Around the Metro," p. 52)*. The "access" portion of the network—the spokes—ferries signals out to residential neighborhoods and individual office buildings. These access lines connect to the "collection ring," which transports signals around a metropolitan area, linking telephone company service centers and other major traffic centers, such as Internet service providers and large universities.

Technological advances are helping unsnarl both the collection ring and the access lines. Fiber optics, which already dominate the collection ring, are replacing more and more of the residual copper in the access lines as well—in effect, paving over dirt paths with smooth, modern asphalt. And new optical transmission technologies are stuffing more data into the networks that are already in place.

PACKING BITS AND WAVELENGTHS

The heaviest lifting in a metro system is typically done by the collection ring, which runs all the way around the region, providing local access as it goes. To burst through the bandwidth bottleneck here, engineers have two basic choices: they can crank up the bit rate on a single beam of light traveling through a fiber, or they can multiply capacity by using several wavelengths as information carriers. In the second alternative, known as "wavelength division multiplexing," each fiber carries multiple light beams of different colors—with a different digital signal encoded in each beam. The more wavelengths you can pack in, the more information you move. (These "colors" are actually different shades of infrared and are invisible to the eye.)

Both approaches are now being tried by the companies that run the metro loop. Various technical problems make it tough to raise the bit rate. But in encouraging recent developments, two optical-networking leaders—Ciena and Nortel Networks—have demonstrated single-

No-Fiber Diet

Stringing optical fiber to a building in a crowded downtown helps data flow smoothly but disrupts life in the physical world. One way to avoid digging holes that become money pits is to keep the laser transmitters but throw away the fiber. Bolt a transmitter on one building and a receiver on another, and the laser beam could go straight through the air. No one needs to rip up the streets. As long as one building is linked to fiber, the system can be up and running much faster than a new fiber link, at a fraction of the price.

The idea sounds as good today as it did when proposed some 40 years ago as an application of the newly invented laser. But attempts back then to make a practical through-the-air optical link foundered. Rain, snow and fog got in the way too often for reliable communications. But the idea is still alive, and, thanks to technological progress in the intervening years, quite well.

To contend with the weather, San Diego-based AirFiber builds an array of laser links between buildings. If thick clouds block one or two beams, the system automatically reroutes the signal to beams that have clear sailing. As long as individual links span no more than 500 meters, AirFiber says, the system should stay up and running. Other companies have their own variations on this technology and claim data rates of up to one gigabit per second over a range of a few kilometers.

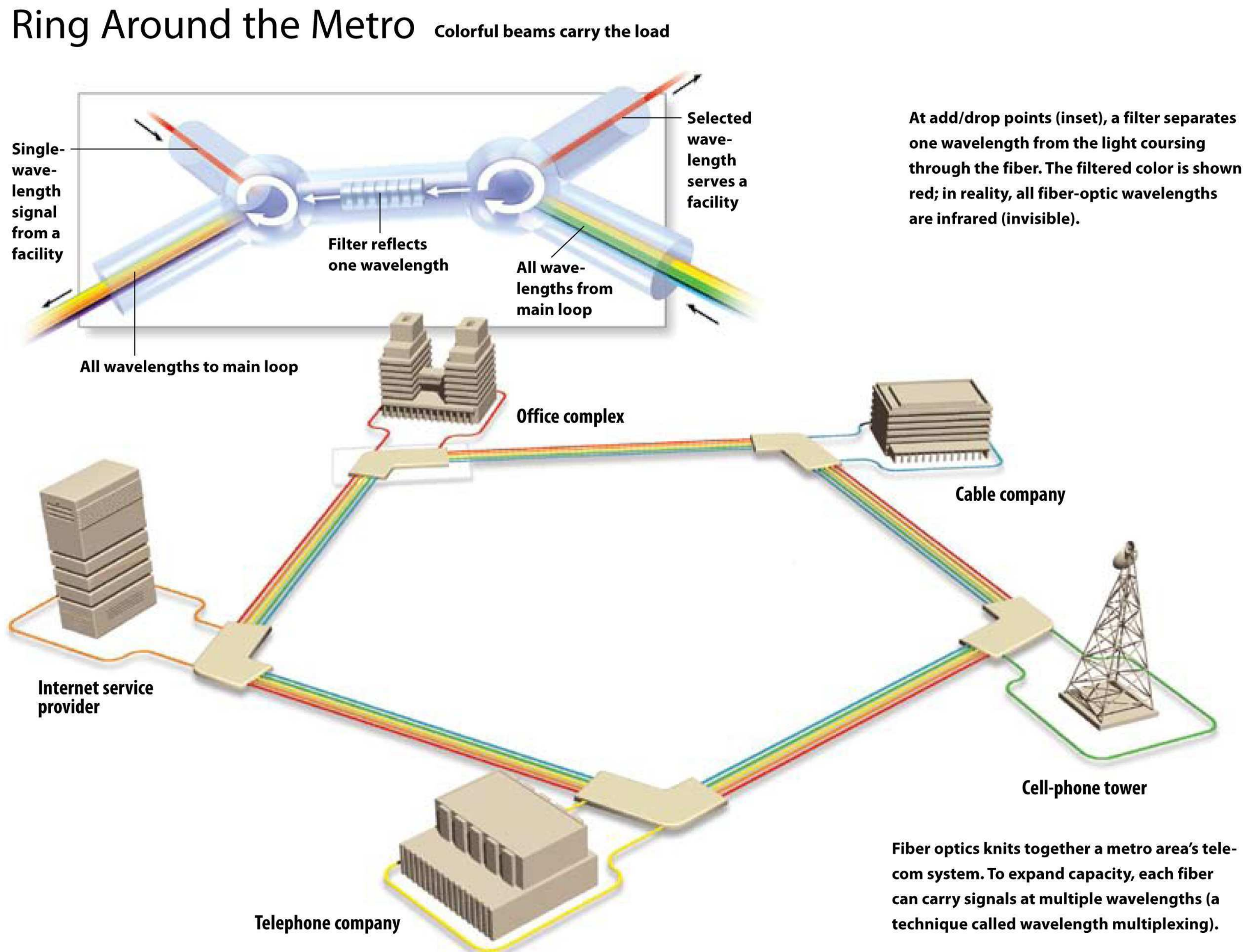
Such free-space optical systems are most attractive in downtown areas, where buildings are closely spaced and construction costs high. Fiber-optics market research firm RHK, for instance, would like higher-speed access for its South San Francisco offices; but fiber doesn't yet reach the 12-story high-rise where it occupies most of one floor. Direct transmission could be the answer.

However, the technology is still in the demonstration phase, and important questions remain about reliability and performance. Dale Niebur, director of fiber marketing for access systems at Corning, is skeptical. "Tall buildings sway a couple of feet," he says. "Getting the lasers aimed right is going to be a challenge."

wavelength transmission of 40 gigabits per second over lengths of fiber typical of a metro network. That's a big leap over the 2.5 gigabits per second at which today's fastest metro networks operate. Taking this research feat out of the lab and under the streets, however, will require advances in the electronics that manipulate the signals, since standard chips don't yet operate that fast.

That leaves the second option—packing more channels into a single fiber—as the avenue of choice. But though wavelength division multiplexing is routinely used in long-distance transmission lines, its application in metro loops has proved more challenging. One reason is the need for a complete change in costly terminal equipment. Most existing metro fiber systems transmit a single signal at a wavelength of around 1,300 nanometers. The optical devices that slice the spectrum into the greatest multiplicity of channels, however, work best at the longer wavelengths (around 1,550 nanometers) that backbones commonly use.

Metro networks can't simply plug in new lasers to take advantage of the best multiplexing technology. A 1,550-nanometer laser costs as much as 10 times more than a comparable device that emits 1,300-nanometer light, and whole new sets of elaborate optics are needed to combine and separate the different wavelengths. This factor has slowed the introduction of wavelength multiplexing into metro networks. The market for this technology "is not going to take off for at least another two years," asserts Mark Lutkowitz, vice president of optical-networking research at Communications Industry Researchers, a market research firm in Charlottesville, VA.



At add/drop points (inset), a filter separates one wavelength from the light coursing through the fiber. The filtered color is shown red; in reality, all fiber-optic wavelengths are infrared (invisible).

Fiber optics knits together a metro area's telecom system. To expand capacity, each fiber can carry signals at multiple wavelengths (a technique called wavelength multiplexing).

BURROWING IN

A trip around the metro collection ring shows that it is stuffed full of fiber; copper has been almost banished. But in the access lines at the fringe of the network—the links that connect the ring to homes and businesses—fiber still coexists with its old-fashioned counterpart. "Fiber is getting further into the access network every day, but it's got a long way to go," says Brian McFadden, president of photonics networks at Nortel Networks.

That's understandable. Even though fiber is cheaper to operate and more stable than copper, established companies can't afford to rip out all of their installed cables at once. "The amount of infrastructure is enormous; even changing out a few percent a year is a tremendous investment," says Verizon's Elby. That's why a consortium of telecom equipment makers and service providers is pushing to develop evolutionary pathways to bring fiber ever closer to the homes and offices that use the network.

The key technology in this evolution, called a passive optical network, extends the reach of fiber optics further out to the fringes. In order for this technique to work, at least some fiber service must already be in place; but passive optical brings fiber to parts of the network now served only by copper.

Here's how passive optical works. A transmitter at a central facility generates an optical signal at one of two standard telephone-system data rates—155 or 622 megabits per second. This signal is a composite, which includes information for as many as 32 users. A "passive" optical coupler—which requires no electrical power—then divides this signal among fibers that link directly to end users or to other branching points. Equipment at the end of each of those fibers sorts out the signals, relaying only the ones in-tended for the local user. The central transmitter can reallocate bandwidth among customers almost instantaneously.

For a telephone company, passive optical networking offers an attractive way to extend the reach of optical fiber with minimal fuss. The passive design keeps hardware, operation and installation costs down. Moreover, the sensitive equipment needed to transmit, receive and reroute optical signals is kept safe inside buildings at the ends of the system. And since the passive optical network requires no electrical power between its end points, it generally needs less maintenance than networks based on active components.

A dark-horse technology that has recently joined the metro network, called Gigabit Ethernet, ups the speed ante even further. These systems use fibers to transmit information in the Ethernet format commonly used for office computer networks. Their data rates of one gigabit per second leave other access-line technologies in the dust. A gigabit is 1,000 megabits; gigabit-per-second transmission would, for instance, whisk away the entire contents of a CD in less than a second.

In a Gigabit Ethernet, a single fiber pipeline goes to a central switching point. This Ethernet aggregator, as it is called, distributes signals out to as many as 200 fibers. Each output fiber—like the input fiber—can carry up to one gigabit per second for short bursts, but the total output speed cannot exceed the input. An aggregator box the size of a telephone booth can serve more than 200 homes within a radius of up to 10 kilometers. That's well beyond the reach of digital subscriber lines, or DSL—the phone company service that provides broadband connections through copper cable.

Gigabit Ethernet can work as a cheap end run around telephone companies for delivery of broadband access. That's why an Ottawa, Ontario-based nonprofit consortium of companies and universities called Canarie is promoting the technology for broadband connections to cash-strapped schools. In the United States, Veradale, WA-based startup World Wide Packets has developed its own version of the technology for rural telecommunications. It is field-testing a system in Ephrata, WA, for the Grant County Public Utility District.

HIGH-FIBER DIET

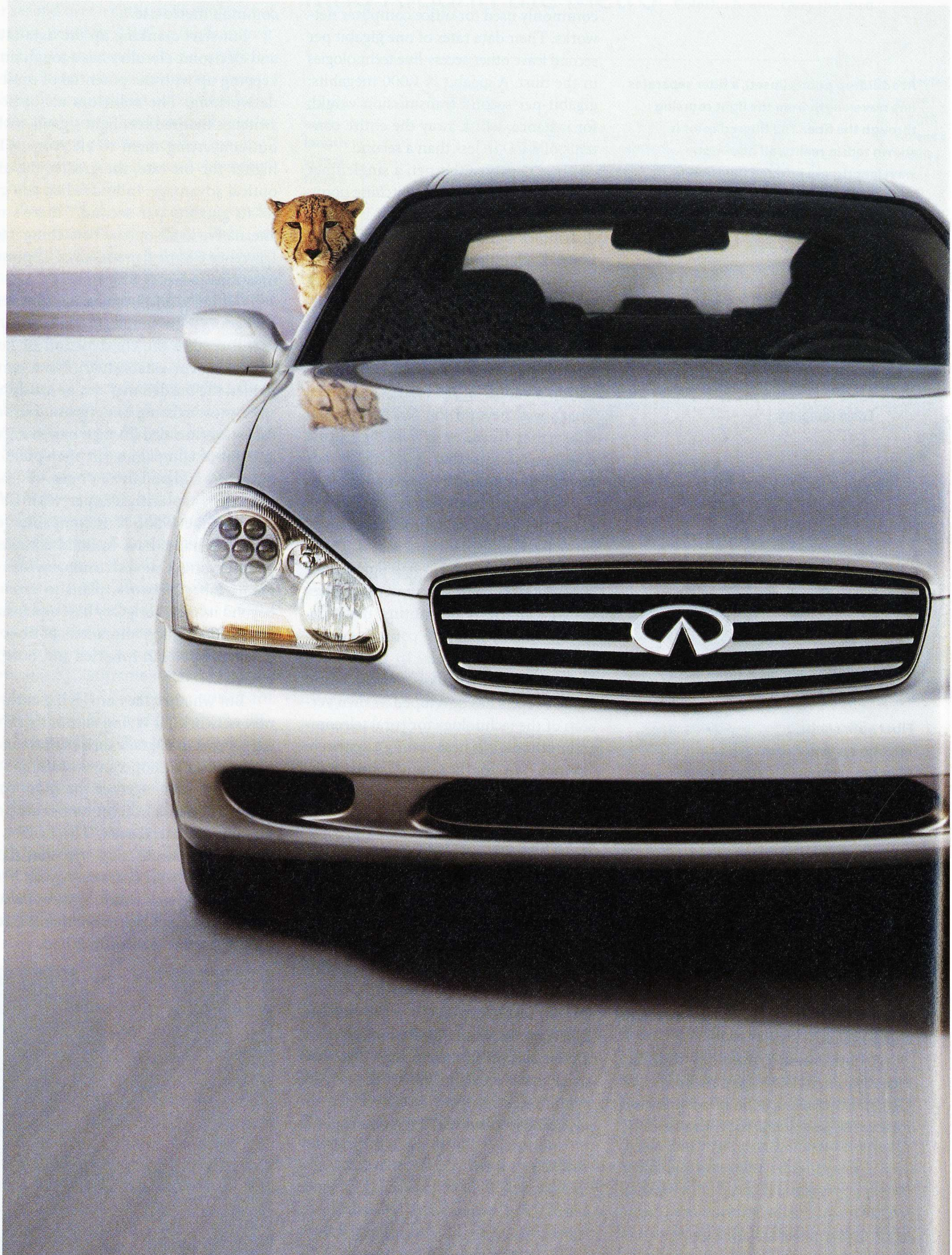
Merely weaving more fiber into the metro network won't solve all the problems that crop up in urban areas. Today's systems rely on a sometimes awkward mix of electronic and optical technology. Tiny lasers launch data-bearing light beams into optical fibers. At the other end, the light strikes a photosensor, which converts the on and off flashes into an electrical signal that electronic switches direct to its proper destination. Such electronic switching works fine at the modest speeds of 2.5 gigabits per second that are now in common metro use.

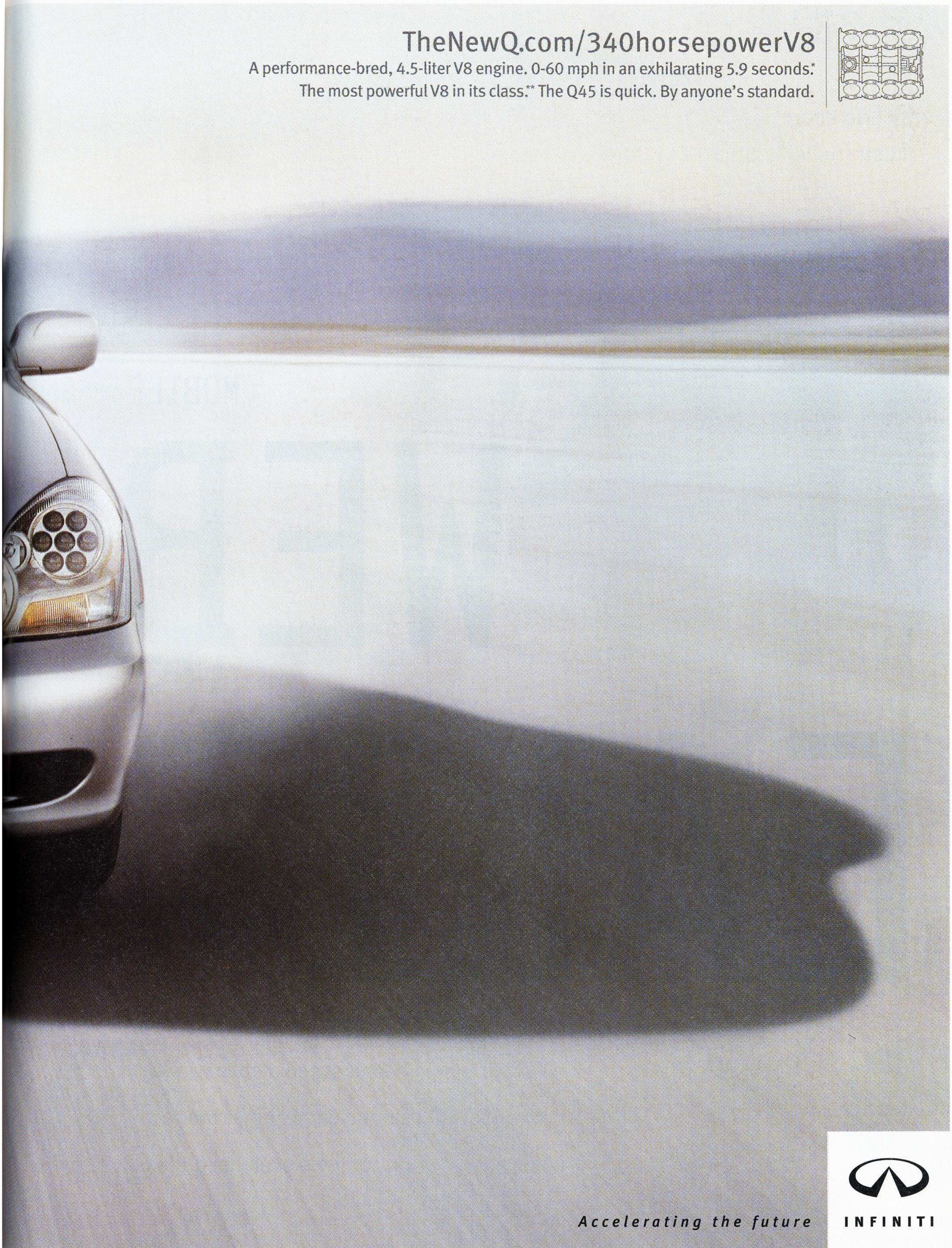
But start cranking up the data rate, and electronic circuitry has a tough time keeping up with the potential of optical networking. The solution: all-optical switches that redirect light signals without converting them to electrons. The higher the bit rate, the greater the all-optical advantage. Indeed, when you get to 40 gigabits per second, "there's no alternative to all-optical" switching, says Lawrence Gasman, president of Communications Industry Researchers.

Getting to an all-optical metro system isn't going to be simple, though, because it will require the construction of new networks. For established phone companies, the burden may not be crushing, since most existing underground urban cables are threaded through buried ducts, and phone companies can often pull out old cables and pull in new ones—as they did when replacing copper with fiber cables in the 1980s. New companies, on the other hand, have to build complete new networks. One such company, Metromedia Fiber Network, plans to expand beyond its New York City base and install almost six million kilometers of fiber in 67 cities in North America and Europe by 2004.

But whether they are laying entirely new networks or trying to modify existing systems to upgrade their performance, the builders and operators of the metro loops that knit together the most concentrated populations of homes are performing a crucial task. The backbone and the corporate networks that flank the metro loop get faster every year. If the metro bottleneck is not broken, broadband will remain little more than a clever idea that some techies once had. ◊

While fiber optics has taken over much of the metro network, old-fashioned copper still lurks at the fringes.

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MOBILE WEB VS. REALITY

Telecommunications companies are spending billions to prepare high-speed mobile wireless networks. But it's not clear whether the technologies will work…or if we even need them.

John Chapman brims with enthusiasm. The director of Hewlett-Packard's mobile and wireless strategy has just signed a three-year research agreement with NTT DoCoMo, the cellular spinoff of Japanese telecom giant NTT. The goal? To brainstorm the infrastructure for a wireless network with such abundant capacity that, according to Chapman, "we will no longer bother to measure it." Hewlett-Packard has allied itself with NTT DoCoMo—whose name means "anywhere"—because the Japanese firm is the world's leading mobile-Internet provider. An estimated 72 percent of Japanese cell-phone owners routinely connect to the Internet, compared with a mere six percent in the United States. Chapman believes that if Hewlett-Packard can offer Americans rich streaming video, data, graphics and voice over a high-speed network that reaches every street corner, subway platform, beachfront and backyard, they will sign up in droves.

How to build this broadband wireless network is the burning question. Telecom companies would need to spend hundreds of billions of dollars to catapult today's narrowband cell-phone infrastructure to broadband. This is no mere "upgrade." Today's meager cell phones and wireless Web devices connect to the Internet at a laggard 9,600 bits per second, less than one-fifth the speed of the average desktop modem. And even a desktop modem doesn't qualify as broadband. Its speed has to be at least quadrupled for users to enjoy instant Internet access and to view full-motion video with movielike quality.

Furthermore, the Wireless Application Protocol by which today's mobile devices connect to the Internet typically supports only clunky, dumbed-down, black-and-white versions of a few hundred Web sites deliberately tailored to a tiny screen. Despite the constant commercials for "smart" phones and wireless wonder-gadgets from the likes of Sprint, AT&T, Palm and Kyocera, most people are frustrated by the embryonic "wireless Web."

Given the huge expense to license new broadband spectrum from national governments, technical and regulatory battles over which emerging communications protocols to use, plus the need to overhaul cell towers and mobile devices, some experts wonder whether the benefits are worth the trouble. Do we really need streams of data flowing from cell towers everywhere so we can watch a CNN video clip as we step off a midtown curb, paying a steep per-minute fee for the privilege?

Maybe not. Outside of Japan, enthusiasm for this scenario seems to be waning, even among the telecom companies that would charge you for it. The cost appears so astronomical that voracious consumer demand for such amenities as digital video and music would be needed to cover it. No U.S. or European surveys indicate such demand exists, or that consumers would pay the premiums.

What is clear, however, is that consumers who are strolling or driving want reliable cell calls, paging, e-mail and fast, easy access to the entire full-color Web. None of which, in fact, requires broadband. Having taken a reality check, some telecom executives are promoting a new vision: improve the cellular system enough so consumers get uninterrupted phone calls and instant access to the Web over a trendy handheld device while they're outdoors, and reward them with streaming, multimedia, broadband brilliance once they step indoors, at home, office or hotel, on trains or on planes. When the frenzy over broadband dies down a bit, is that what the future is really going to look like?

NATURE'S SPEED LIMIT

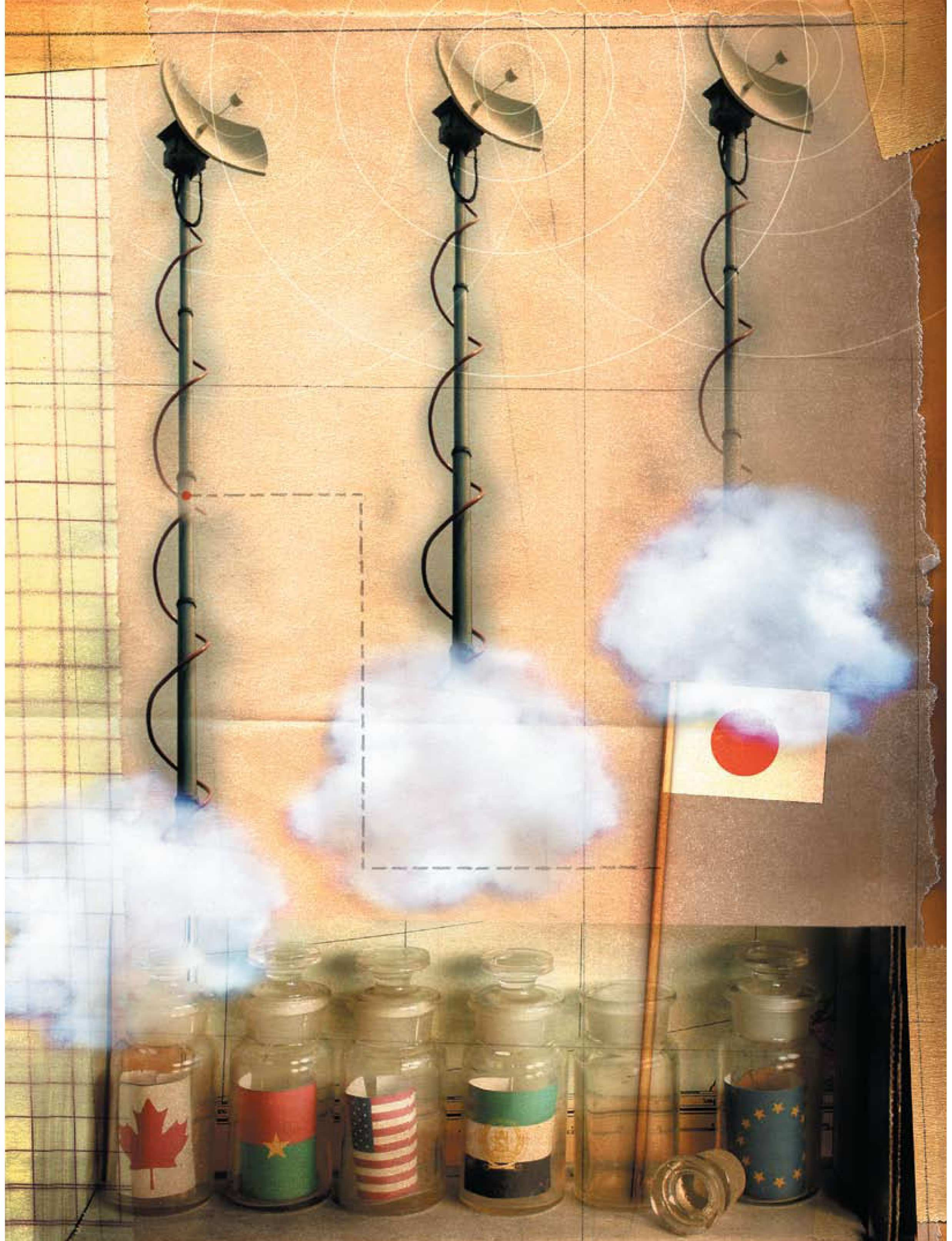
This new, hybrid vision remains contrarian in the wireless industry, largely because mobile broadband evangelists like Chapman believe in "build it and they will come." Their companies are proposing a jumble of competing protocols to move us beyond today's second-generation, or 2G, digital cell-phone networks. They plan to roll out so-called 2.5G systems that combine voice and data this year in Japan and Europe, and in 2002 in the United States. Japan claims it will soon follow with the third generation, or 3G. Yet nobody seems certain when 3G, the standard that will support true broadband applications, will actually be implemented.

Working against its rapid appearance is a fundamental law governing data communications that was laid down way back in telecom's primordial era: 1948. That year, Claude E. Shannon of Bell Labs stated that the maximum amount of data that can be transmitted through any channel is limited by the available bandwidth (the amount of radio-frequency spectrum it occupies) and by its signal-to-noise ratio (the signal to be communicated versus interference).

Both limits are strikes against mobile-wireless communications. A wireless channel can only use the portion of the spectrum approved for it by the International Telecommunication Union and licensed by one of its 189 member states. The licensing fees are appalling: carriers spent more than $46 billion for the 3G spectrum in Germany alone. At those prices, a carrier must maximize the payback of its channels by packing as much data as possible into as narrow a frequency band as possible—a practice that runs counter to the principle of filling a broad band with data-intensive multimedia streams, which is, technologically, the optimum strategy. To resolve the conflict, carriers must devise technology that can send signals faster in tight bands.

To make matters worse, the medium through which the signals flow—the earth's surface atmosphere—is a very noisy place these days. Cell-phone signals careen off buildings, hillsides and each other, creating interference and decay. To improve fidelity, manufacturers must

NOBODY SEEMS CERTAIN WHEN 3G, THE STANDARD THAT WILL SUPPORT TRUE BROADBAND APPLICATIONS, WILL ACTUALLY BE IMPLEMENTED. WORKING AGAINST ITS ADOPTION IS A BASIC LAW OF DATA COMMUNICATIONS.



boost the signal power or reduce the noise. But they can't increase power because the Federal Communications Commission and its European and Asian counterparts restrict the electromagnetic radiation cell towers and handsets can emit. Besides, raising a handset's power level kills its batteries.

No surprise, then, that engineers focus on reducing noise. This game began in earnest in the mid-1990s, when digital cell phones started to replace analog versions, increasing voice clarity dramatically. Even though telecom companies had to spend billions of dollars to add digital transceivers to their cell towers, the upgrade quickly paid for itself, because it also allowed the providers to cram many more simultaneous voice calls into the same slice of expensive bandwidth, with less interference.

THE SOLUTION IS FOR THE CELL-PHONE SYSTEM TO PROVIDE ALWAYS-ON

PROVIDE WIRELESS BROADBAND TO OUR HANDHELD DEVICES INDOORS. THIS

LOOK BEFORE YOU LEAP

There are two basic schemes for packing as many digital calls as possible into the available bandwidth. The Time Division Multiple Access protocol, an early format championed by AT&T, has evolved into the Global System for Mobile Communications, now a near-universal standard in Europe and Japan. Code Division Multiple Access arose as the main alternative, adopted by Sprint and GTE, and by the end of the decade it reduced noise better than the time division method and packed more data into a single channel.

The leading 3G standards approved by the International Telecommunication Union are based on the code division protocol. But to implement them, telecom companies must license expensive new spectrum and overhaul cell-tower and handset technology. After initial blind enthusiasm, few U.S. carriers now seem in a hurry to make massive investments. Tom Crook, director of technology research for Sprint PCS, speaks for many when he says, "I don't see us doing 3G anytime soon."

Technical assessment groups like Adventis in Boston also say that, on a real street corner, 3G data rates won't come close to the maximums industry proponents quote, which are based on pristine lab conditions. In a recent compilation of technical and investment studies examining eight proposed broadband technologies, Adventis concluded that only three could realistically achieve average data speeds faster than a desktop modem's. And those three would roughly double the speed, far shy of the quadrupling needed for real broadband performance.

Ken Hyers, an industry analyst with Cahners In-Stat Group, says that the daunting expense and dubious technical results of 3G are causing U.S. carriers to "take a wait-and-see attitude. They're saying, 'Let's see how much bandwidth our customers are really going to use.'" If all they want are simple Web services such as online restaurant directories, the answer may be, not much.

Rather than taking the true broadband leap, Sprint PCS and others have decided to test the waters using 2.5G technology, which uses the same spectrum as current 2G networks and requires only a relatively minor hardware upgrade. Although 2.5G can't achieve true broadband data rates, it does offer one huge advance: it's "always on"—instantly available, 24 hours a day. You won't have to dial in and wait 30 seconds while your mobile device connects to the Internet. Instant access changes your relationship to the Internet profoundly. Studies show that people in homes with instant access through hard-wired systems such as digital subscriber lines and cable modems use the Internet three times as much as people who must dial in each time. When you're mobile, any delay is even more discouraging and may stop you from accessing the Net altogether.

So who really needs 3G, then? Some of the canniest telecoms have begun to blur the distinction by defining their 2.5G technology as 3G. Anil Kripalani, a senior vice president at Qualcomm, says, "We know how to push the envelope." Like other U.S. proponents, he sees no need for carriers to jump to the real 3G. Thus the world's telecom disparity could continue, with America leaning toward 2.5G, Japan intent on 3G, and Europe and the rest of Asia vacillating in between.

Yet even if the 3G dream touted so boldly within the industry fades away, it won't have been in vain, since it is what has motivated carriers to move to 2.5G standards. Engineers are devising intriguing cell-tower transceivers and handset antennas to help ensure that wireless users get the maximum bandwidth and strongest signals available, regardless of how many Gs they're pulling. Yet incompatible transmission protocols still pose a problem. Each cellular device uses a microprocessor-radio chip that supports only one protocol. A phone using a code division protocol requires a different chip than a phone using a time division protocol, and different 3G phones from AT&T and GTE, say, would use different chips even if they were both based on a code division protocol.

One technology, known as software-defined radio chips, could provide a solution, according to Benny Bing, a leading wireless authority at the Georgia Institute of Technology Broadband Institute. Still in prototype, software-radio chips can switch among protocols, filtering techniques and detection schemes. At any moment, a mobile device with software radio inside could switch seamlessly among American, European and Japanese telecom standards, as well as competing transmission protocols *(see "The Universal Cell Phone,"* TR *April 2001).*

BEATING THE AIR RAID

The prospect of designing a winning broadband mobile architecture has attracted legions of ambitious technologists. The question remains, however, whether they can ever supply enough real communications power—remember Claude E. Shannon—for you to check out that CNN clip as you walk around downtown. Rather than trying to rev up the cell-phone network to deliver a broad-

INTERNET ACCESS OUTDOORS, AND CABLE-TV AND COMPUTER NETWORKS TO ARCHITECTURE COULD BE BUILT RELATIVELY QUICKLY AND INEXPENSIVELY.

band Internet, perhaps we are better off with parallel systems, one for phone (which already exists) and one for data (under construction).

"There's really no big reason why the good old cell-phone system should survive or thrive as the wireless Internet," says Teresa H. Meng, a groundbreaking wireless researcher at Stanford University who is now chief technology officer of wireless-chip maker Atheros Communications. Instead, Meng says, telecom companies could place wireless data transceivers on every building and utility pole. Each transceiver would cover a small area, or "nanocell," ranging 200 to 300 meters in diameter. Together they would create what Meng calls a "wireless fabric." Because the transceivers would be so close to users, they could send clear, high-speed wireless signals over narrow bandwidths, at frequencies that fall into the "industrial/scientific/medical" portion of the spectrum, which regulators make available free and is used by cordless phones, garage-door openers, medical instruments and factory machinery. And handsets could get away with low power output, conserving batteries.

In tests at its Sunnyvale, CA, labs, Atheros's chipsets are reaching data rates hundreds of times faster than desktop modems—true broadband. Not burdened by having to carry voice, they can be far speedier than 3G schemes, which supply voice and data together. Meng also says, "The data communications industry has the upper hand. Because the cell-phone industry is heavily regulated and totally standardized, improvement has been made very incrementally—as in 3G versus 2G. Those technologies are 15 years old." Even some cell-phone pioneers, like Martin Cooper, who developed the first portable cell phone at Motorola in the early 1970s, agree that a dual system might be more practical than 3G *(see "Everyone is Wrong," p. 82)*.

Blanketing our towns with nanocells may seem far-fetched, but Meng insists it would cost less than acquiring pricey 3G spectrum. Chip Elliott, principal scientist at Verizon's BBN Technologies, concurs. He estimates that a network covering a large city would require $20 million up front in equipment, plus $5 million in annual network costs. Not bad, considering that the 3G spectrum for New York City alone was auctioned for billions of dollars, and the required system upgrade will add much more to the cost.

Freed from voice, data-only systems could provide a quicker, easier path to inexpensive, broadband Internet service, perhaps even that streaming CNN video on the street corner. Indeed, Metricom's commercially available Ricochet mobile data-only service already operates twice as fast as desktop modems. Technologists are testing much faster data-only schemes, too. The consensus is that Orthogonal Frequency-Division Multiplexing, a format currently used to transmit high-definition television in Europe, could provide the best option. Rajiv Laroia, chief technology officer at Flarion, a leading commercializer of the scheme, says his company will offer equipment later next year.

Of course, there are many hurdles to a data-only infrastructure. The industrial/scientific/medical spectrum could rapidly become overcrowded, forcing carriers to license pricey spectrum after all. Interference could degrade the quality of those multimedia Web streams. There is no agreed-upon transmission protocol, leaving data-only services open to the incompatibility that besets 3G. To avoid walking around with several different gadgets, we'd need that software-radio device to switch handily between voice and data modes. Stray beyond urban areas, furthermore, and it's hard to imagine a nanocell on every fifth fence post.

Which brings us back to the contrarian vision of a hybrid network: a 2.5G cell-phone system providing clear voice, paging and always-on Internet access to our handheld devices outdoors; and the cable-TV and computer-network wiring already in place indoors providing the full-blast broadband experience—which the handheld can tap into.

This architecture could be built relatively quickly and inexpensively. High-speed, broadband Internet will soon be available in many indoor environments, as companies such as Cisco Systems and Juniper Networks busily string fiber-optic cable to homes and businesses. A simple wireless transceiver in the corner of a lobby or living room would feed your mobile device; you could access the high-speed networks being built into modern trains and planes the same way. This scheme also dovetails nicely with what is happening inside numerous businesses, where aging, hard-wired local-area networks are being replaced with "fixed" indoor wireless networks, which are cheaper and easier to install and readily support broadband data rates. It would be simple for your mobile device to latch on to this infrastructure.

Looking toward the end of the decade, you may end up using 2.5G wireless for convenient cell-phone calls and Web access while traipsing around town, then cut over to a fixed-wireless network when you step into the coffee shop, subway station or meeting room, perhaps using a software-radio Web phone that switches between voice and data as needed. Flip open your 2.5G CellMate while walking down Main Street to call home, then convert to data mode to download a shopping list after your spouse tells you about a sudden party you didn't know you were hosting. When you step into Mammoth Grocery, CellMate switches over to the store's fixed-wireless network so you can quickly check Online Wine to see which vintage will complement dinner. The store's map appears, leading you to the wine aisle. You point CellMate at the checkout's infrared scanner to debit your bank account. And that indoor/outdoor hybrid system, rather than the grand vision of "3G," might be what the future really looks like for broadband wireless. ◊

Join an online discussion of this article at www.technologyreview.com/forums/bandwidth.

Eye candy: Project leader Lance Evans sports Nomad, the head-mounted retinal scanning display, which provides big views of little images.

If displays and keyboards don't get better, increasing wireless bandwidth won't mean diddly.

By Erik Sherman
Photographs by Mark Gilbert

LITTLE BIG SCREEN

Mike Foster's Palm Vx could cost him money today—lots of it. The professional speaker, whose specialty is telling businesses how to exploit new technology, has a chance to make $240,000. But he must respond promptly to an international organization that has requested a speaker for 24 of its chapters. At $10,000 a pop, it's an opportunity Foster can't pass up. But critical information he needs to close the deal is locked in an e-mail attachment that is slow to open. The e-mail itself is next to impossible to view on his PDA's low-resolution screen. Someone else might reach the meeting planner first and get the job—and the payday.

"It's a big game, and the quicker you get your information, the better you can respond," says Foster, who might not be able to connect his laptop to the Internet until he arrives in Chicago at 10:30 at night. To make matters worse, the airline lost some of his baggage, including a keyboard accessory that would let him type an intelligible reply, and responding with the Palm's handwriting recognition software isn't generally as fast as typing.

Make no mistake—this isn't a knock on the Palm Vx specifically. As people become dependent on digital organizers, cell phones, pagers and other portable devices to connect to the Internet, many are frustrated as the flood of information online narrows to a trickle. The interfaces, including screens that display data, as well as keyboards and voice recognition systems that deliver it, are too small, too slow and too awkward to process information effectively. Web sites become unusable, e-mails constrained, and graphics are eliminated. As a result of these clunky interfaces, a bottleneck problem that previously existed between Internet service providers and their subscribers—a link known as the last mile—also occurs between a handheld's processor and its owner.

That critical distance, known to insiders as the "last three feet," could put at risk the billions of dollars invested in wireless connectivity. Even if vendors solve the challenges of the last mobile mile, it could all be for naught if they cannot cover the distance between the hand and the face. The dilemma has engineers, programmers and designers going back to the drawing board for new ways to twist open the information valve. Microdisplays, foldable keyboards and better voice recognition systems are just some of the solutions. But will people use them? And are handheld devices equipped to operate them? Let's take a look.

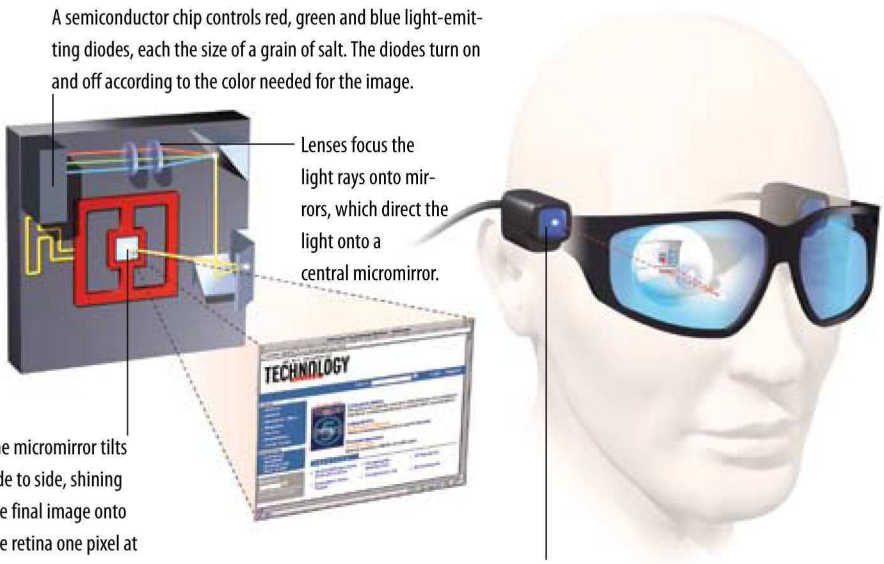
SIZE MATTERS

When it comes to portable devices, people's expectations outstrip what they demand from a desktop. "Users using a mobile device are much more sensitive to the time it takes to perform a task than they are when they are sitting at their desk," says Mike Flom, CEO of Portable Internet in Park Ridge, NJ. Yet the screens and displays of mobile devices remain thoroughly inferior to those of PCs. "I don't care how many bits per second you've got, if I've got a [five-centimeter by eight-centimeter] display, there's only so much I can do with that," says Eric Schaffer, founder and CEO of Human Factors International, a Fairfield, IA-based software usability consulting firm.

Not only are the screens small, but their resolution remains stubbornly low—only a fraction of that available even on the

No Monitor Required

A semiconductor chip controls red, green and blue light-emitting diodes, each the size of a grain of salt. The diodes turn on and off according to the color needed for the image.



Lenses focus the light rays onto mirrors, which direct the light onto a central micromirror.

The micromirror tilts side to side, shining the final image onto the retina one pixel at a time.

The technology used in these goggles can also be incorporated into cell phones, watches or other handheld devices.

The view through goggles equipped with a retinal scanning device is a full-monitor-sized transparent (or in some versions, opaque) image floating in space at about arm's length.

SLIM FILMS

cheapest computer monitors. As a result, each letter or image needs more screen space to be legible. That limitation plus a miniscule screen adds up to one big frustration.

One solution: larger screens. The extra space might come from a flexible screen that unfolds like a map. Plug it into a pocket computer and you have as much visual real estate as you'd find on a desktop, or at the very least on your cumbersome laptop. Indeed, that development could spell the end of the laptop. "If I had a palm-sized device that…I could fold out to be a full-sized display with a competent processor…and one of those fold-up keyboards," asks Flom, "do I need a laptop anymore?"

Pocket-sized, foldable screens are only a few years away. Both E Ink of Cambridge, MA, and Gyricon Media, a Xerox spinoff in Palo Alto, CA, have been developing thin displays with "electronic ink" technology *(see "Electronic Paper Turns the Page,"* TR *March 2001).* Electrostatic charges orient white microscopic particles suspended in tiny spheres. An underlying circuit controls the charge and whether or not the spheres show as white or dark. The companies are also looking into eventually developing flexible color displays.

Although electronic ink is on the technology horizon, it isn't quite ready for mobile electronics use. The prototypes being developed by E Ink and Gyricon Media provide reflective displays, relying on the environment for illumination. That may be fine outdoors or in a bright room, but not in dim surroundings.

But electronic ink is not the only little big screen solution in the pipeline. Another approach keeps the display small—two centimeters or less in diagonal—but offers good resolution and an effective screen size many times its physical dimension. The solution makes use of magnifying lenses mounted in monocular units or goggles. The magnifiers pump up visuals to the scale seen in conventional full-sized monitors. InViso of Sunnyvale, CA, for example, makes a handheld device that, in conjunction with glasses, offers images 800 pixels across and 600 pixels high—the same resolution as a standard 35.5-centimeter desktop monitor. Large companies are also entering the market, with Sony's Glasstron and the Eye-Trek from Olympus both giving the viewer an image equivalent to a 132-centimeter screen seen from about two meters away.

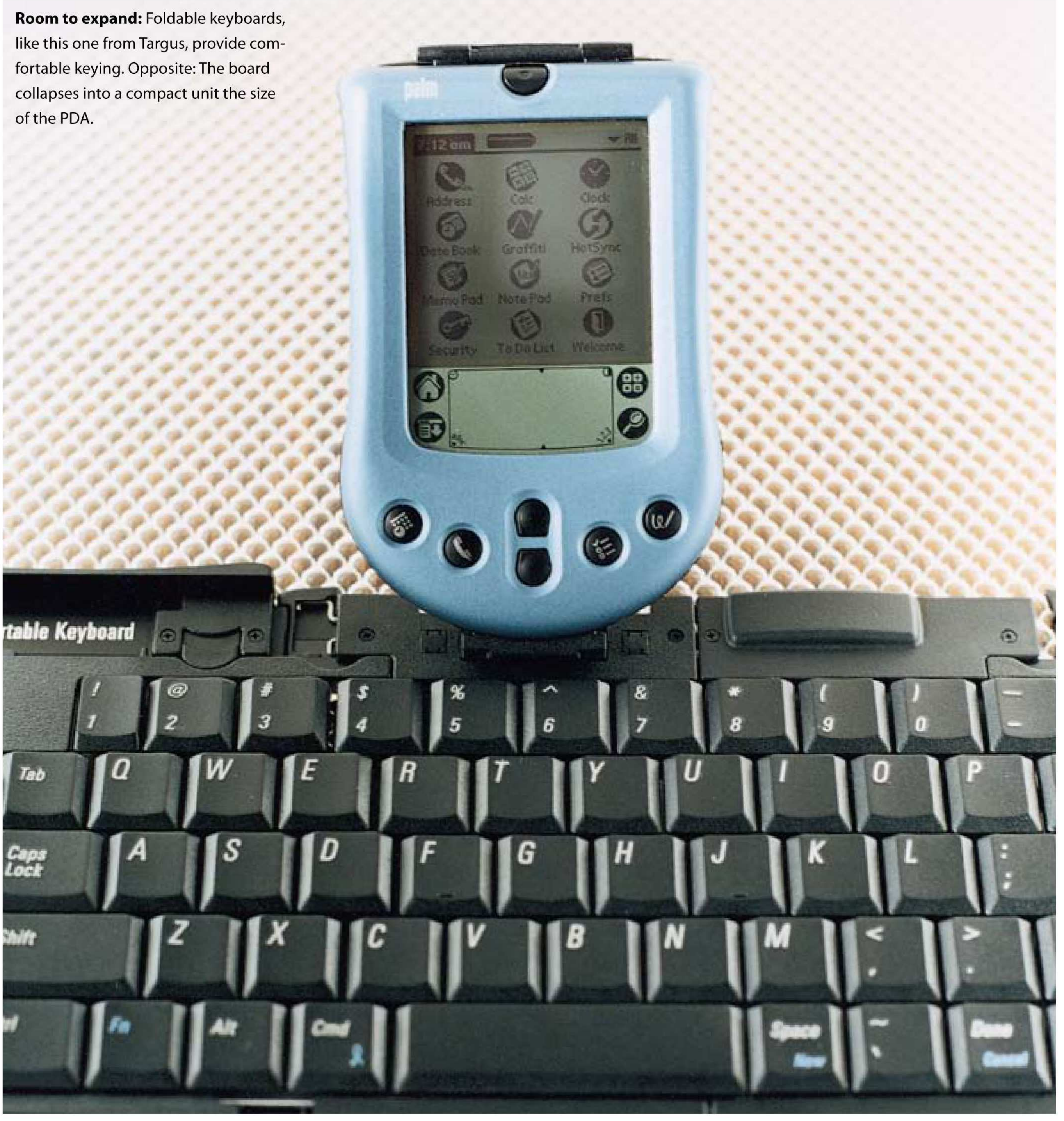
Of course, this approach raises the question: why not just cram more pixels into tinier screens for better resolution? The answer has to do with the physics underlying the most common technology used in handheld screens—liquid crystal displays. These displays are a multilayered sandwich of components backlit by a light source. The light must pass through electrode strips to illuminate the pixels on the surface of the screen. Whether a pixel gets illuminated is controlled by a thin-film transistor connected to the electrode strip. A current flowing from the transistor makes the strip opaque; no current lets light through. But as the pixels shrink, they soon become smaller than the transistors, which then block out the light, whether they're on or off.

Organic light-emitting diodes, a new display technology, eliminate the need for backlighting *(see "A Bright Future for Displays,"* TR *April 2001).* When charged by electrodes, these organic materials emit their own light. Currently, Motorola has

Watch the phone: Samsung puts voice recognition into a conveniently worn phone.

a mobile phone on the market that uses organic diodes developed by Eastman Kodak. And many other big-name corporations are experimenting with the technology as well, including eMagin, IBM's Almaden Research Center, Uniax and Cambridge Display Technology.

While many companies are struggling with the engineering challenges inherent in small screens, one ingenious solution does away with screens altogether. Microvision, a Bothell, WA, manufacturer, actually projects an image, pixel by pixel, directly onto the viewer's retina. The approach is similar to cathode-ray projection in a television. But instead of electron beams selectively lighting spots on a screen, light projects onto the retina, illuminating tiny points and creating the illusion of a 43- to 53-centimeter screen floating in space at arm's length. To view a Web page, people using mobile phones equipped with retinal displays might hold the devices close to their eyes, or they might wear goggles with retinal scanning devices built into the temples *(see "No Monitor Required," p. 66)*. The technology is just starting to hit the real world. The Microvision head-mounted prototype "Nomad"—scheduled for market release this fall—creates a clear, see-through image at arm's length even under the brightest daylight conditions. Eurocontrol, the organization that oversees air traffic control in Western and Eastern Europe, is testing Nomad in a flight control-tower simulator. Freiburg, Germany-based Stryker Leibinger, a manufacturer of surgical instruments, purchased 10 Nomads in late March for clinical evaluation. And the



Room to expand: Foldable keyboards, like this one from Targus, provide comfortable keying. Opposite: The board collapses into a compact unit the size of the PDA.

Mayo Clinic in Rochester, MN, is also considering using Nomad in the operating room.

Designing display systems that offer the experience of a full monitor is one thing, but deciding to use them is quite an-other. The sticking point is the social acceptability of wearing headgear that can make someone look like a lost cyborg. Donning such a device "is a very big issue," according to Robert Steinbugler, manager of the IBM corporate strategic design program. "What you typically find is that a person has to have seen a value for doing that, or seen the idea on someone else before trying it themselves." Cell-phone users may have made it acceptable to wear an earphone to make calls while walking, but covering an eye like some high-tech pirate might still be considered strange, even in a large city *(see "Cyborg Seeks Community,"* TR *May/June 1999).*

SQUEEZING IN

If people get over their self-consciousness about looking like cyborgs, then head-mounted displays only help relieve part of the problem of wireless connection to the Internet. Displays provide "output"—the information coming from the network to the user. The other half of the circle is "input"—sending responses back out into cyberspace. And it ain't easy. "Output is hard," notes Michael Karasick, chief technology officer of IBM's pervasive computing division. "Input is harder."

Just think of what it's like using the keypad of your cell phone to send typed messages. You must press the same key three, even four, times to type a single letter. Some people may thrive on these difficulties: Adam Lavine, CEO of FunMail in Pleasanton, CA, reports from his Asian travels that the Japanese have a word, which translates roughly as "lightning thumb," referring to people who are particularly adept at typing messages on mobile phones. But for those of us with ordinary thumbs, something more comfortable is in order. And it's coming. Targus and other companies sell folding keyboards that work with PDAs. Last fall, Electro-Textiles demonstrated a prototype PDA fabric keyboard that could actually be rolled up for storage.

Some of us won't ever have fingers dexterous enough to do our talking for us. But few of us have trouble talking, and that's where voice recognition comes in. A number of cellular-phone manufacturers, including Motorola and Nokia, have been offering voice recognition for contact lookup for a few years. Samsung has incorporated voice navigation into a wristwatch-like phone. Conversay, which provided the voice technology for Samsung, has also ported its products to the Microsoft Windows CE Pocket PC platform.

However, voice recognition doesn't necessarily make for a good user experience. "In a device, you need to make sure you're not trying to force it to do things more easily done with a single button click," says Williamson.

This could be tough in an area where restricted vocabularies—think "yes" and "no"—are more commonplace than sophisticated sentences. A general interface that would allow anyone to talk freely is overly optimistic, according to Dr. George White, senior vice president of technology at NetByTel, a Boca Raton, FL-based vendor of voice commerce systems. "True speech recognition requires enormous intelligence, which we can't get into these little devices, and it will always be that way," says White. But that doesn't mean more sophisticated voice recognition will never be mobile. For complex voice recognition, White and others think the mobile device will do some preprocessing, then pass the sound over the Internet to a server that can handle more elaborate processing.

Each approach to more fluid input has its champions, but some experts think the ultimate solution will not come from a single technology but from a combination of approaches. Omar Javaid, chairman of New York mobile commerce consulting firm Mobilocity, shares White's skepticism about voice recognition. "We call it the *Star Trek* interface," he says. "In all likelihood, no single method of input will serve, and mobile electronics will probably best serve with a combination of all these methods and others as they become available."

The ultimate interface, some argue, would be the complete integration of human and machine, with chips and sensors implanted under the skin to detect the user's every intent. Issues of social acceptance aside, there may be practical reasons to keep devices at arm's length. Doug Armstrong, CEO of AppForge, which manufactures mobile and wireless software development technology, remembers being part of a Navy research project that was monitoring the brain activity of pilots to try to let them "think" the weapons on their F-14s and F-22s into action. But the result was like telling someone not to think of the word "persimmon"—the pilots would think the trigger word even when they did not want to fire.

At this point, tech consultant Mike Foster, whose Palm may have cost him a payday, would consider almost any high-tech addition to improve his experience. "I can see myself stopping in a restaurant and putting all that stuff on," he says, but only if it were sturdy and durable. In the meantime, he'd settle for a better screen. "I understand the physical limitations, but at some point having 640 by 480 on a Palm in color, that would be great," Foster muses. "I'd pay three times the price for that."

For now, Foster will continue trudging through the Internet, wishing under his breath for improved displays, better keyboards, friendlier interfaces. If vendors build it, he will buy it—as will others, no doubt. But so far, interfaces for handhelds are nothing more than tiny nozzles, and that makes the wireless Internet industry a little nervous, as they watch the flood of data gushing down the pipes. ◊

By Claire Tristram

BROADBAND'S COMING ATTRACTIONS

The hype is that broadband will transform entertainment, changing everything from how we watch movies to the video games that we play. The reality doesn't exactly match up.

Last January Miramax Films, the movie distributor that brought us such modern classics as *Shakespeare in Love* and *Good Will Hunting*, became the first bona fide Hollywood player to make the leap into the world of broadband entertainment when it made its 1999 movie *Guinevere* available as a copy-protected download over the Internet. Web surfers were invited to pay $3.49 on their credit cards for the privilege of skipping the trip to the video store.

Illustration by John Craig

Fuzzy bootleg copies of other movies, such as *The Matrix* and *Blade Runner*, abound on the Web, along with infinite numbers of amateur videos. But *Guinevere* is the first Hollywood movie to be offered online in a legal, non-pirated way. It's an Internet milestone—even if Miramax has chosen one of its less successful films with which to make history. So I decided to give this brave new world of broadband entertainment a try.

DRACULA
CASABLANCA
KING KONG
KATHARINE HEPBURN · CARY GRANT
HOLIDAY
TEST PILOT
BARRYMORE
RASPUTIN AND THE EMPRESS
WIZARD OF
GABLE
LOY
TRACY
TEST PILOT
JEAN ARTHUR
FRANK CAPRA
KATHARINE HEPBURN
POP CORN

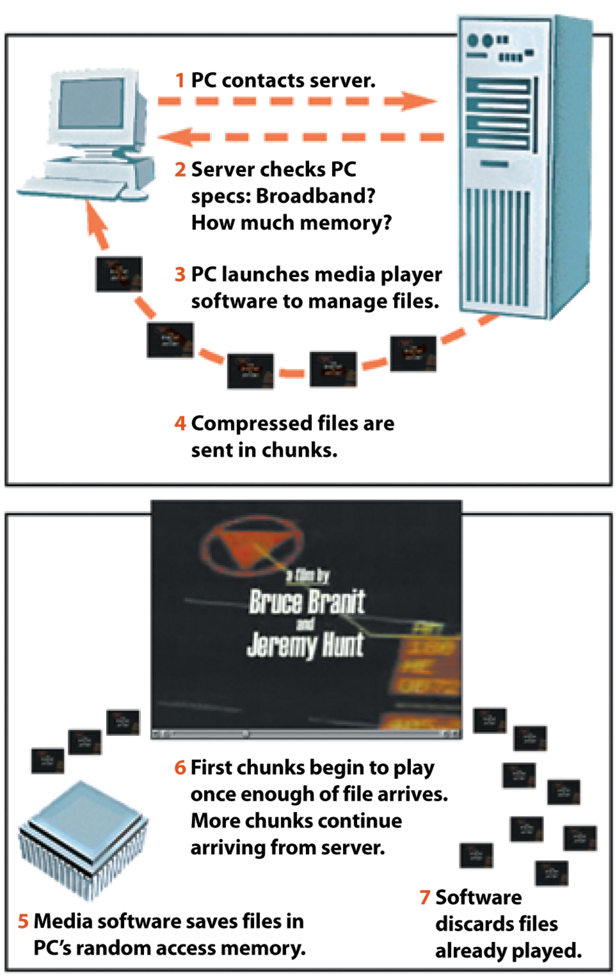
A day and a half later I was still trying. Much of that time was taken up borrowing a Windows-run computer, since Miramax's Web distribution partner SightSound Technologies has yet to support Macintosh; then I discovered I needed two plug-ins before the movie would download itself onto my computer. Using my digital subscriber line (DSL) service, the download itself took one hour and 14 minutes; but add time for locating the required plug-ins, downloading and installing the software, rebooting when asked, and then going back online after the movie finally downloaded to give my credit-card information and pay, and the process easily took two hours. That's 15 minutes longer than the movie. In two hours I would have been watching not the titles but the credits, if only I'd gone the low-tech route and rented from the local video store.

What did I get for the trouble? A grainy film on a computer monitor. The version of *Guinevere* available over the Internet is only about one-tenth the file size of the version available on DVD; as a result, the picture quality is much lower. There is also the problem of milieu. Watching a film—especially one that advertises itself as "a May-September romance with an edge"—while leaning forward staring at a computer isn't exactly a bring-out-the-popcorn kind of experience. Fifteen minutes into the film I gave up and took my dog for a walk.

One of the most pervasive visions of the broadband future is "video on demand," the ability to order up movies and other programming and have them appear promptly on your screen, ready for viewing. Miramax is forging ahead, planning to offer a dozen movie titles online for download by the end of this year. Other Hollywood studios are following suit, citing the lucrative opportunities created by the fact that, for the first time, millions of consumers are gaining broadband access to the Internet.

But in the hour or so it took to download *Guinevere*, I had plenty of time to wonder, Is this it? Is this the best that the creative minds of Hollywood can come up with for the broadband Web?

How Streaming Works



BETSY HAYES

Certainly, broadband Internet connections can transmit large amounts of data at speeds inconceivable only a few years ago. These connections, using either a digital subscriber line service running over the pair of copper wires from the telephone company or a cable-modem service delivered over cable-TV wires, are now in over five million U.S. households. They greatly outperform conventional dial-up modems, increasing the amount of data per second that consumers can reliably receive over a network and into their PCs by up to 50 times.

Still, it isn't nearly enough. At least not for some of the grander visions offered by Hollywood studios and other entertainment companies looking to exploit the bandwidth explosion. Not only will the Internet of the foreseeable future give you a fuzzy version of *Guinevere* after nearly a two-hour wait, but many other promised broadband applications—choose-your-own-replay sports sites, say, or interactive 3-D video games—are also proving to be far more technologically difficult than many had expected.

This doesn't necessarily spell doom for broadband entertainment. But it does mean the future will look quite different from what some Internet pundits predicted even a year ago. Forget about downloading Hollywood movies or real-time video of the soccer championship being played in Brazil. What will work are Internet sites that take into account the limitations of even a broadband Web and nevertheless manage to offer customers something new.

"What consumers want from broadband is still something of a question mark," says Ford Cavallari, an executive with Adventis, a Boston-based management consulting firm. "But it's going to have nothing to do with two-hour movies, no matter what kind of fire-power you see coming out of Los Angeles."

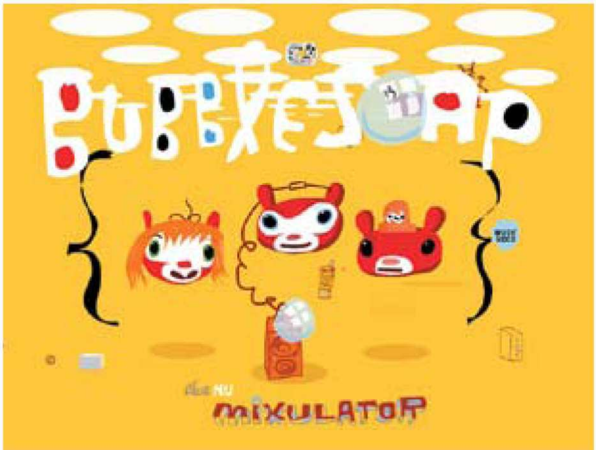
MUSIC MANIA

Despite broadband's limitations, people are signing up in record numbers. It took cable television more than 30 years to reach 15 million customers; broadband Internet services in the United States alone may hit that mark by 2005, about 10 years after the technology was first introduced commercially. Why is broadband catching on so quickly?

In a word: Napster.

"The single most important reason people have signed up for broadband is they want to download music files faster," says Cavallari. "Next there will be some sort of equivalent to Napster for still pictures, where people can share images or display what they've created with their digital cameras." Indeed, broadband provides a real benefit to anyone trying to download large digital files: a five-minute song, for example, will take less than a minute to download on a broadband line, compared with 10 minutes or more on a dial-up line.

But outside the music- and baby picture-swapping community, some of



What works? Hokey animations like "Bubblesoap," featured on www.jotto.com (upper left), and "Capitol III," featured on www.atomfilms.com (above), don't strain our broadband connections; while films lasting less than three minutes, like "405," featured on www.ifilm.com (left), don't strain our patience.

the most popular applications on the Web can still run afoul of bandwidth shortages. The problem is not so much how many bits of data per second are theoretically able to reach your desk, but rather the maddening variability with which those bits arrive. Broadband users experience wild swings in performance, from near-instantaneous delivery of large files to slower-than-dial-up speeds. Sites that succeed on the broadband Web take these limits into consideration.

Broadband users experience wild swings in performance, from near-instantaneous delivery of large files to slower-than-dial-up speeds.

Broadband line speeds can be affected by a whole host of factors, from how far the customer's computer is from the central office providing DSL service (farther equals slower) to, in the case of cable modems, how many other people are trying to download files over the same service. Cable-modem service shares bandwidth among many users; the more traffic there is, the less performance any single user gets. This variability, combined with an Internet protocol that wasn't designed to make bits arrive on time and in order, often produces video, even at broadband speeds, with that characteristic stop-and-go quality.

Not surprisingly, stop-and-go performance is particularly hard on interactive games. Because packets of information from different computers may travel the Internet over different routes and thus arrive at their destination out of sequence, it's impossible to predict precisely when a keystroke or mouse click will have the desired effect online. "Say you want to develop an online basketball game," says Mark Blecher, vice president of marketing and sales for Electronic Arts, a maker of computer games. "One player shoots, the other player attempts to block. The winner will be determined more by what the network does than anything the players do."

The stop-and-go problem stems from the way that video traveling over the Internet arrives at our machines. Most video available over the Internet is in a streaming format; that is, only a portion of the video file is downloaded into your computer's electronic memory at any given time. After you view it, it is discarded to make room for the next bit of video *(see "How Streaming Works," p. 72)*. Streaming means you don't need to use up disk space on your PC to view a video, and that you don't need to wait long to start watching. But quality takes a hit whenever Internet routers decide to send packets in routes other than a direct line from the server to your computer. One alternative is to download a video file to play later on your desktop processor. That's what I did to watch *Guinevere*, and as I found out, this method has plenty of its own problems. Although you avoid network hiccups, you still must contend with the file's size.

The most effective sites avoid both of these problems with content you can access easily and look at quickly. In other words, they appeal to the "lean-forward" market—computer monitors rather than

La-Z-Boys. Take for example artist J.otto Seibold's Web site at www.jotto.com; in many ways the site is a perfect example of what works in the broadband Internet world. The site uses animation rather than video, so it works well within the bandwidth constraints of cable modems and digital subscriber lines: it's far easier to stream the simple drawings of an animated short feature than it is to make video streams work, since so much less information needs to be transmitted. The site is interactive in humorous ways, appealing to the lean-forward crowd—your mouse can make a dog run around chasing birds, or make an animated character get on a bicycle and race after an ice-cream truck.

Videos that respect the Web's limitations are also flourishing on sites that aggregate the work of many artists, such as AtomFilms (www.atomfilms.com) and iFilm (www.ifilm.com). These Web sites are meant as a platform to give exposure to unknown or emerging directors, and films on these sites are short, usually less than 15 minutes long. Directors on these sites often experiment with images that take advantage of the jerkiness of online video: characters, for example, might run in slow motion.

Take the film "405" on the iFilm Web site. Created on home computers by Bruce Branit and Jeremy Hunt, friends who in their day jobs create effects for television shows, the film depicts a jumbo jet landing on top of a sports utility vehicle in the middle of a Los Angeles freeway. The film "405" manages to tell a story in less than three minutes, and uses effects—like blurring the edges of the plane to denote speed—that translate effectively into the broadband medium.

SHOW ME THE MONEY

Besides the technological obstacles to making video over the Internet a part of America's viewing habits, there are also economic obstacles. In truth, no one has figured out how to make broadband entertainment pay. One reason is inherent in the medium itself. While TV broadcasters incur a large up-front cost to deliver their signals everywhere, once that investment is made, the cost per viewer to deliver a program becomes ever smaller as the audience grows. The cost of broadcasting a television program is the same, whether it is watched by one person or 60 million.

Not so with the Internet. The cost of delivering a video stream to an individual over the Internet doesn't decrease as the audience grows. Content providers must pay per-stream licensing costs to RealNetworks or Microsoft or Apple Computer, so that customers can view video in RealPlayer or Windows Media Player or QuickTime. Internet service providers also charge on a per-stream basis to carry the traffic. And expensive technology may be required to manage simultaneous requests for the same material if a site becomes wildly popular. So costs expand proportionally with the audience—and the provider never gets the benefit of scale economies.

"The early model for broadband has been TV," says Joe Laszlo, analyst for Jupiter Research, a Web advisory company. "But broadband is exactly the opposite of the broadcast world. Your costs go up as your audience grows." According to Jupiter, the cost of providing video streams to a thousand viewers is nearly twice the amount advertisers are willing to pay to reach those viewers. Unless some fundamental shift occurs in consumer demand, so that people will pay for broadband entertainment, or in advertising prices, so that entertainment sites can charge more than they do now, broadband Internet sites will never be profitable.

> No one has figured out how to make broadband entertainment pay. This gloomy reality is reshaping how content providers view the Web.

This gloomy economic reality is reshaping how broadband content providers view the Web. "People are now turning to a subscriber model instead of relying on advertising," says Laszlo. "There's more potential there. But with the quality of service so unpredictable, it's difficult to say whether sites will be able to charge enough to cover their production costs."

As a result, many of the companies offering original broadband content—Icebox, Pseudo Programs, Digital Entertainment Network and others—failed within the last year or so. What's left in many cases are Web sites that use stream-

No Land of Milk and Honey: Video-rich Heavy.com got milk, but it isn't depending on becoming profitable despite a million visitors a month.

ing video to promote their own products. Movie trailers. *Survivor* updates. World Wrestling Federation interviews. To name just a few. Sites whose purpose is to promote successful programming in other media, such as TV.

"What you see developing online is the use of three- to four-minute promotional clips," says Daryl Schoolar, industry analyst for Cahners In-Stat Group in Scottsdale, AZ. "Until the cost to deliver streaming media comes down, that's primarily what you are going to get."

Even many serious broadband content developers view the Internet as just a stopping ground, using it as a test market for eventual theater showings or television syndication. Heavy.com is a mix of alternative music and crassly humorous video clips aimed at a young, urban, mostly male audience. Its "Behind the Music That Sucks" animation sequences—a takeoff on VH1's *Behind the Music* docu-mentary series—skewer everyone from Britney Spears to Eminem. While the site gets a million visitors each month, cofounder Simon Assad sees it primarily as a way to promote new programs, build an audience and eventually graduate to television.

"We're expecting the Web site to be profitable, but we're not depending on it," says Assad. "Instead, we're using the Internet to promote our television programming. I don't need a broadcast license, I don't need a distribution network, yet I'm broadcasting television right now over the Internet."

UP CLOSE AND PERSONAL

What does all this mean for the future of the broadband Web? For one thing, the services that will survive and flourish are likely to be those that don't need massive audiences to be profitable. According to Jupiter, while 15 million U.S. households will have broadband Internet access by 2005, these households will still be far outnumbered by customers using dial-up modems to access the Internet. "Two-thirds of us will still be using dial-up in 2005," says Laszlo.

The broadband Internet is, however, great for person-to-person file exchanges. You'll likely see more ways to share information that takes advantage of broadband's faster speeds—Napster-like sites that allow sharing of personal photographs and videos, perhaps even allowing for on-site editing. Sportscapsule is one such service: it allows high school coaches and parents to upload their videos of local sporting events, and to edit them with appropriate prerecorded comments from TV football commentator John Madden. "For video to make sense on the Internet, it needs to be personal," says Lawrence Rowen, vice president of marketing and sales at Sportscapsule. "Television can take care of the mass market. We're servicing a market that may only include 30 people."

It may not be the type of application that Hollywood moguls drool over, but you are also likely to see an evolution of personal communications on the broadband Web, from textual e-mail and instant text messaging to picture mail and video-enabled instant messaging. Successful broadband applications are almost certain to evolve toward this person-to-person sharing over the Internet rather than the downloading of mass-audience movies that are available elsewhere.

While a few years ago the Web seemed poised to threaten cable television, the technical and economic limi-tations of the medium are now much clearer, and the threat is correspondingly reduced. Though Miramax and other Hollywood studios might be exceptions, even large entertainment companies are developing more realistic expectations about broadband use. For example, in July 2000 Blockbuster announced an exclusive twenty-year deal with broadband service provider Enron Broadband Services to deliver movies over the Internet; last March, Blockbuster killed the deal.

"It's finally sinking in that streaming video will never be as good as broadcast television," says Cavallari. "But there will be many things for which it will be good enough."

Good enough, and perhaps even better for the populist kind of communication and entertainment that makes up the best of broadband today. The limitations of the broadband Web have created a fertile ground for innovative forms of entertainment to flourish, whether they be three-minute animations that are too raw to find an audience in broadcast TV, or three-minute highlights from last week's high school football game that can be shared with a proud grandmom a thousand miles away. And in the end, it may be exactly the limitations of broadband that will allow the Web to evolve in unpredictable and interesting ways we've only just begun to appreciate. ◊

Join an online discussion of this article at www.technologyreview.com/forums/bandwidth.

COURTESY OF WWW.SPORTSCAPSULE.COM

Be Your Own Producer: Sportscapsule lets customers edit and share video footage over the Web.

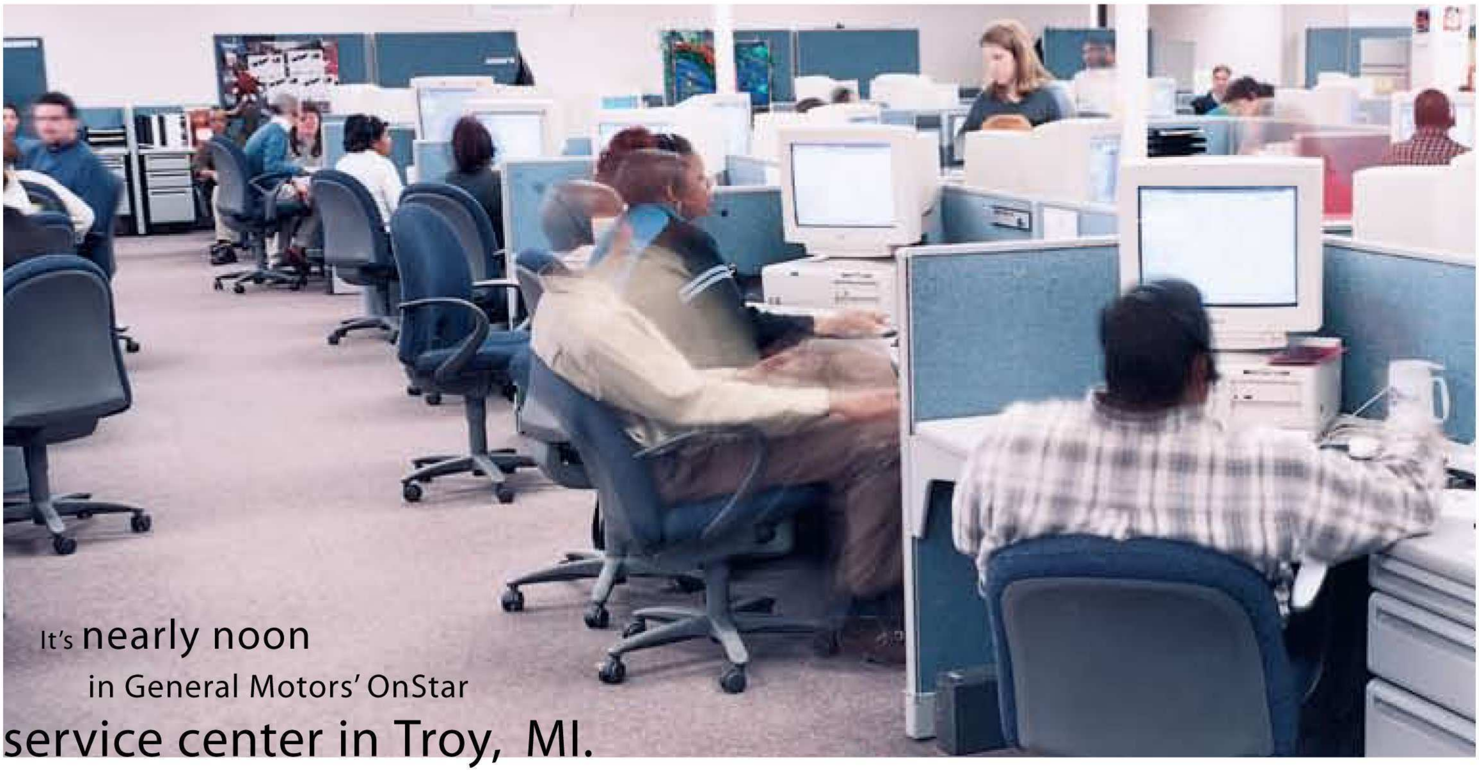
Digital cockpit: A telematics-ready Dodge MAXXcab concept car.

THE COMMUTER COMPUTER

If your car is your refuge from the wired world, look out—a new field called telematics could soon put e-mail, news and MP3s in the driver's seat with you.

By Robert Buderi

Photographs by Bernd Auers



It's nearly noon in General Motors' OnStar service center in Troy, MI.

Perhaps 50 people are in their cubicles, peering at computer screens—and while the place isn't exactly jumping, it hums. A woman on the road in Greenville, TX, wants directions to the Mary Kay center in Dallas. Thanks to the car's Global Positioning System receiver and wireless connectivity, the OnStar advisor can see a map showing the vehicle's exact location. She tells the driver Mary Kay is 102 kilometers away, and guides her to the nearest freeway on-ramp. At another terminal things are more urgent: "Mr. [Jones], this is the OnStar center. Your emergency button has been pressed. Are you all right? Mr. Jones, are you all right?" (He is; it turns out the button was hit in error.)

It used to be people got in their cars and were out of touch for however long it took them to get to their destinations. Cell phones changed that—with exceptions depending on coverage zones and interference. More recently, OnStar and similar plans such as Mercedes-Benz's Tele Aid and BMW Assist have provided built-in wireless links between cars and call centers where operators give directions or summon emergency assistance; some systems unlock doors remotely for locked-out drivers and even provide "concierge" services such as locating the nearest ATM or Chinese restaurant.

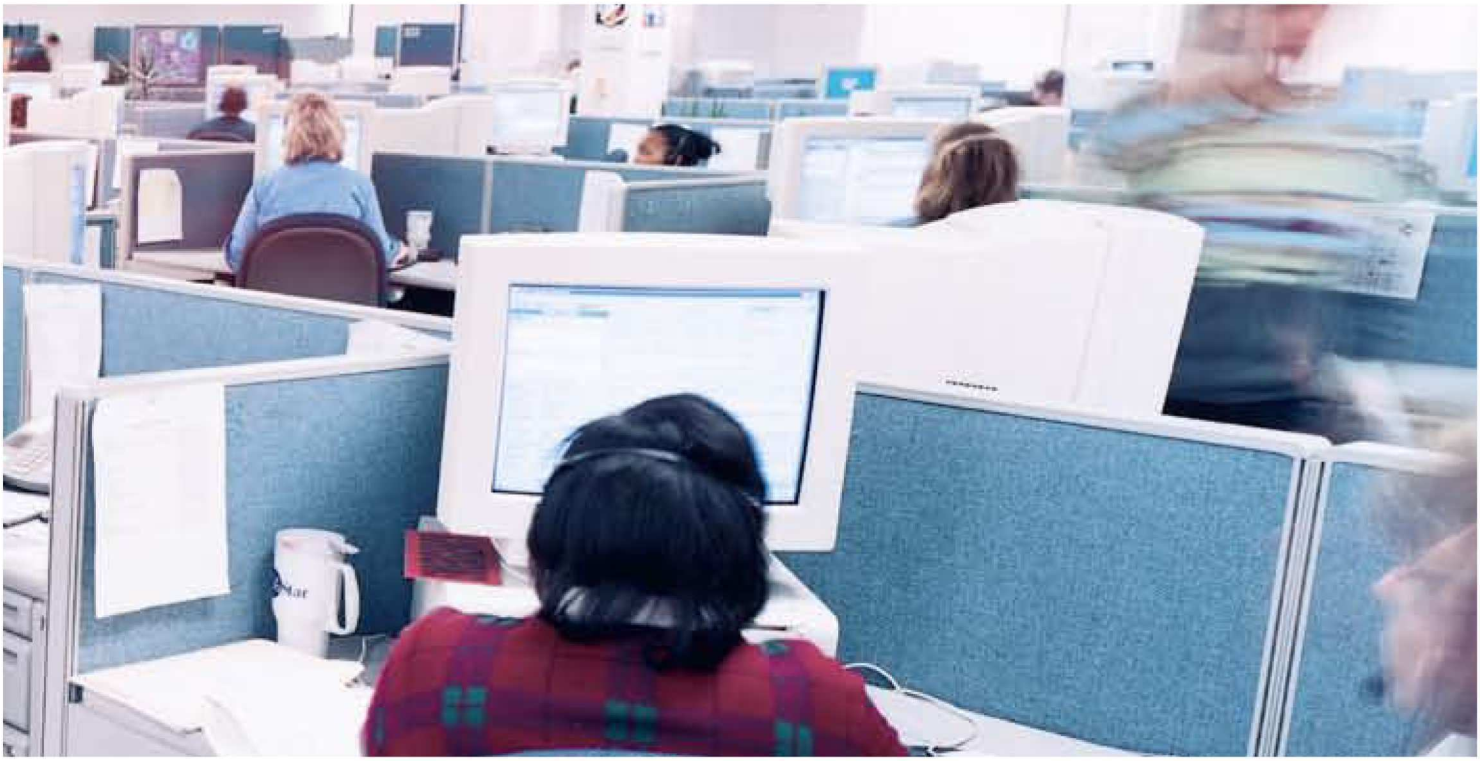
But automakers are hoping that what's available so far is just an appetizer. Faced with dwindling margins and keen to build customer loyalty in the face of intense competition, carmakers are pouring millions into Internet-based systems that would enable drivers to get e-mail, automated directions, tailored news, stock quotes, sports scores, music—even games for the kids in the back seat. At the movement's heart is a blossoming field called telematics—wireless voice and data communication between a car and somewhere else. Already a $5.3 billion business, telematics could reach $30 billion by 2010, according to Michael Heidingsfelder, partner and senior vice president of Roland Berger Strategy Consultants in Troy, which tracks the auto industry. Calling telematics "the next revolution" in auto electronics, Heidingsfelder says it "will change the landscape of the auto industry in terms of technology content, vehicle design and profit streams."

Although the vision of car as Internet portal is striking, it's far from clear how much data people actually want in their cars—or how much they'll pay for it. Telematics developers still debate the interface—voice or screen or some combination thereof—and whether the proposed flood of offerings will make driving more dangerous. As with any new communications technology, wars over which "standard," or format, will dominate remain to be fought. But while such constraints will slow the vision's realization, one thing is certain: the car will never be the same.

STAND ASIDE, AAA

Telematics was born of technological, economic and societal trends that collided in the mid-1990s. Wireless networks were becoming established features of the telecommunications landscape. Carmakers found themselves facing many obstacles that had confronted computer companies as hardware products became low-margin items and they turned to services to build customer loyalty and profits. Highway congestion and longer commutes led the average American to spend 340 hours a year in cars as a driver, 201 as a passenger. Combine, and presto: the auto becomes an extremely compelling marketing target for information technology services.

First onto the track was Ford Motor. In 1996, it offered Lincolns with "RESCU"—mainly for emergency assistance. But Ford expanded slowly, and GM roared into the lead. Initially an option on three 1997 Cadillac models, OnStar is now offered on 32 of GM's 54 North American brands, and the company plans to extend it to all its cars. GM jealously guards OnStar revenue figures. But when you figure the basic price is $199 a year (first year free) and $399 for premium service, that's a heady potential windfall. Which may explain why a host of competitors have come out of the pits *(see "Your Car as Internet Portal," p. 81)*.



It also provides compelling reasons to tap Internet services that could both attract more customers and also hold down costs by automating the system—two keys to making telematics profitable, which it won't be until carmakers achieve the economies of scale needed to pay back their massive investments in the telematics infrastructure. Online automotive services fall into three main categories: productivity, convenience and entertainment. The first includes such things as e-banking, stock quotes and audible e-mail. Convenience covers route-guidance, weather information and news and sports updates. Entertainment includes MP3 music, games and movies.

The basic idea in all three categories is to use the vehicle as a "thin client" that carries the essentials for wireless communications—antenna, receiver, transmitter and the like—but does not have expensive storage or processing power. Instead, subscribers go to a special Web site and fill out a personal profile that lists the e-mail accounts and other information they want. Computing is handled by remote servers, so upgrading software and adding new services doesn't require changes in the vehicle.

The pulse of telematics: The OnStar service center in Troy, MI (top), is staffed around the clock. Drivers can summon service agents, seek emergency help or make a phone call at the touch of a button (bottom).

But while the thin-client model is near universal in telematics, systems from different carmakers vary wildly in their details—particularly the interface. A driver uses OnStar, for example, by pushing one of three buttons and talking to an operator or to the automated system via speech-recognition software, with responses coming through the vehicle's sound system. But some competitors believe a voice-only interface is not enough. It's here the vision becomes most fun—and fanciful—as the Internet-enabled concept car takes to the road.

PORTABLE PORTAL

Take Quick-Scout, a telematics package Siemens Automotive hopes to deploy commercially in 2002. Siemens wants to offer people a visual interface with their wireless services. But building a liquid crystal display into the dash is expensive, so the company plans to borrow a display—and storage and processing power—from a Palm Pilot or other handheld device that would slip into a docking cradle.

That would not only hold down costs but also provide in-vehicle access to electronic address books, phone lists and schedules. It would also offer more seamless connection between the car and the rest of the driver's life—since whatever was downloaded in the vehicle could be carried outside, and vice versa. "That's where we think we're going to get the high take rates," says Harry Asher, senior engineer for Siemens Automotive's Driver Information Systems group in Auburn Hills, MI. "With a system like this, the car in every way can become like a portal to the Internet and the world."

Siemens already has prototype versions of the system running. Slide a Palm V into a cradle mounted in front of a Dodge Durango's main console, start the car and the telematics program

Games to GPS: The back seat of a MAXXcab (top) hosts a game console. Siemens's Quick-Scout (bottom) offers GPS-based route guidance.

springs into action. Four choices appear on the Palm's screen: Navigation, Traffic, News, Messages. Turning and pushing a knob on the cradle—or soon a simple voice command—selects the choice you want.

Say you need directions to an appointment. Select Navigation. The Palm shows various submenus: Address Book, Points of Interest, Street Addresses and Recent Destinations. No matter which submenu you choose, you can either enter an address directly or just the first few letters of your contact's name, and Quick-Scout will scour the Palm's directory and flash the corresponding address on the screen. Accepting the address starts things going: "Calling service provider," a tinny voice reports.

Instead of linking to a call center and having you talk to an operator—humans are both expensive and a potential bottleneck if telematics systems and services expand as anticipated—Quick-Scout locates your position by GPS and sends a request to an information services provider. The service company's system calculates the route and downloads turn-by-turn directions—all in about 40 seconds. To help you get oriented, the Palm screen first presents an area map of your location. Once you're moving, the scene shifts to a closer view of the street you're on, with big arrows showing the correct route. Voice prompts help ensure you get things right: "Please make a legal U-turn ahead."

In the same way, you can access traffic information, news and messages, including e-mail, which Quick-Scout renders aloud. And, says Asher, the system won't lock you into one automaker's vehicles, as OnStar does.

DaimlerChrysler also likes visual displays. Last fall, Mercedes-Benz's Tele Aid began making Internet-based services such as stock quotes and news accessible as text displayed on the dashboard screen that is already standard on luxury cars for things like navigation and audio control. (OnStar made similar features available nationally this year with its speech-only Virtual Advisor option.) But as costs fall, DaimlerChrysler hopes to offer similar services on more mainstream vehicles.

One big focus of DaimlerChrysler's current telematics R&D is entertainment. A Dodge MAXXcab's back seat boasts two kids' stations, each with a video-game controller, and a shared central screen for playing games or watching movies. Steve Buckley, DaimlerChrysler's manager of electric product innovation, demonstrates how a prototype ultrasonic loudspeaker technology from MIT's Media Laboratory called the audio spotlight can create up to four audio zones—for the driver and three passengers—that are effectively inaudible to each other. "If your child's watching the latest Pokémon movie in the back seat, I don't know about you, but I don't want to hear it in the front seat," he says. "I want to play MP3 files."

Similar systems are central to just about everybody's car of the future—and even though the jury is still out on their exact form, autos are undergoing a transformation to get ready. Many new cars have already become antenna farms, carrying separate aerials for AM/FM and GPS, and two for dual-band cellular. Coming down the pike are antennas for satellite radio, short-range wireless and maybe TV.

All this sets the stage for even more exotic telematics applications. Many automakers expect that eventually every car will monitor its own systems. If your vehicle notices a problem, it may communicate that information to your garage, and even consult your calendar to schedule a convenient service appointment.

Your Car as Internet Portal

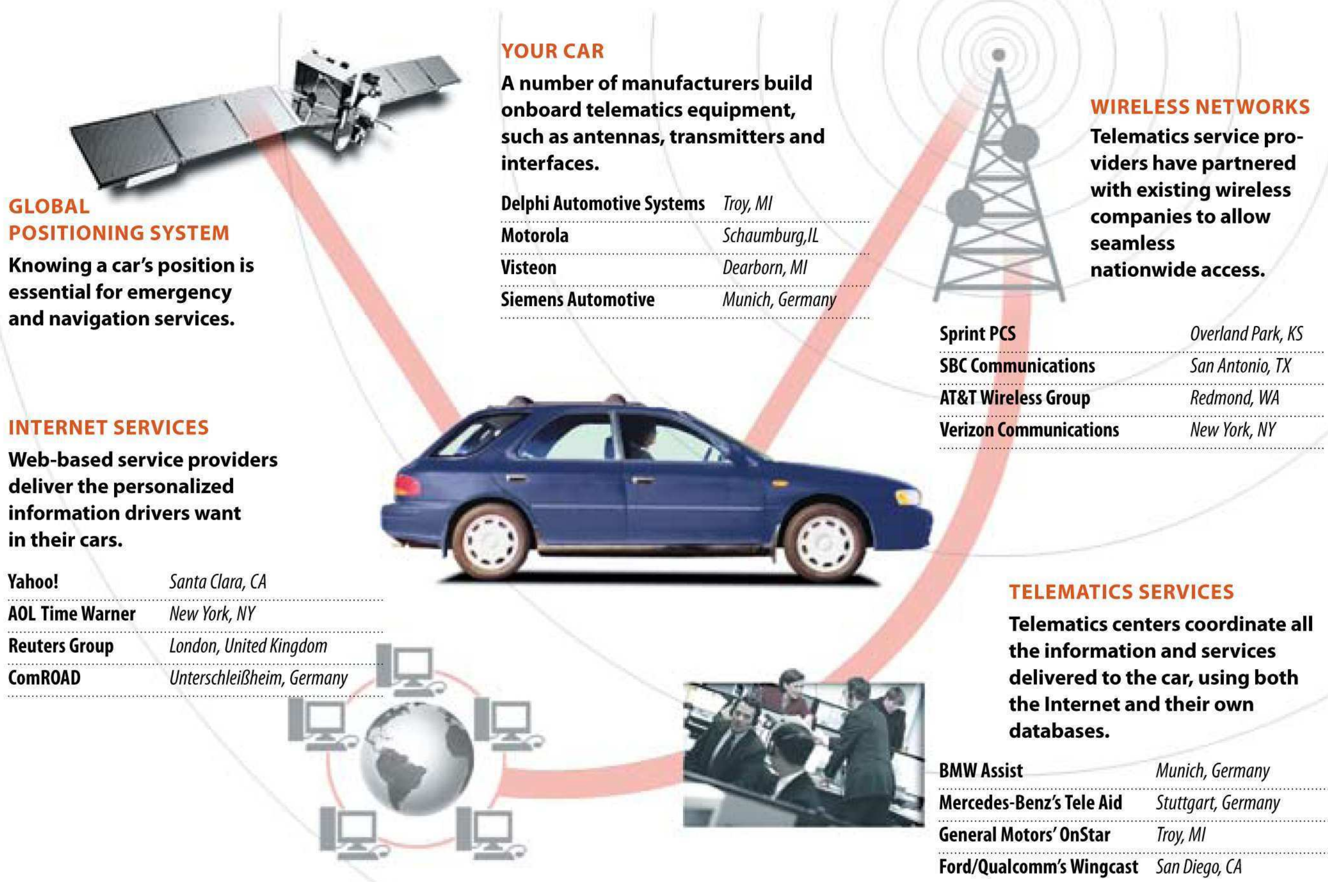


ILLUSTRATION: BETSY HAYES; SOURCE: ROLAND BERGER STRATEGY CONSULTANTS

Sensor data about the car's speed and location might also be used to update traffic reports. And telematics gurus gush about the "information filling station." Bandwidth suffers when the receiver is in motion, limiting the amount of data deliverable to a moving car. So one idea is that when you pull up to a gas station or convenience store your car could also fill up with information using a short-range wireless protocol such as the already available 802.11b standard. Says OnStar's chief technology officer Dennis Walsh, "When [the car] is stationary you can access local networks of malls, loading music and so forth."

I BRAKE FOR REALITY

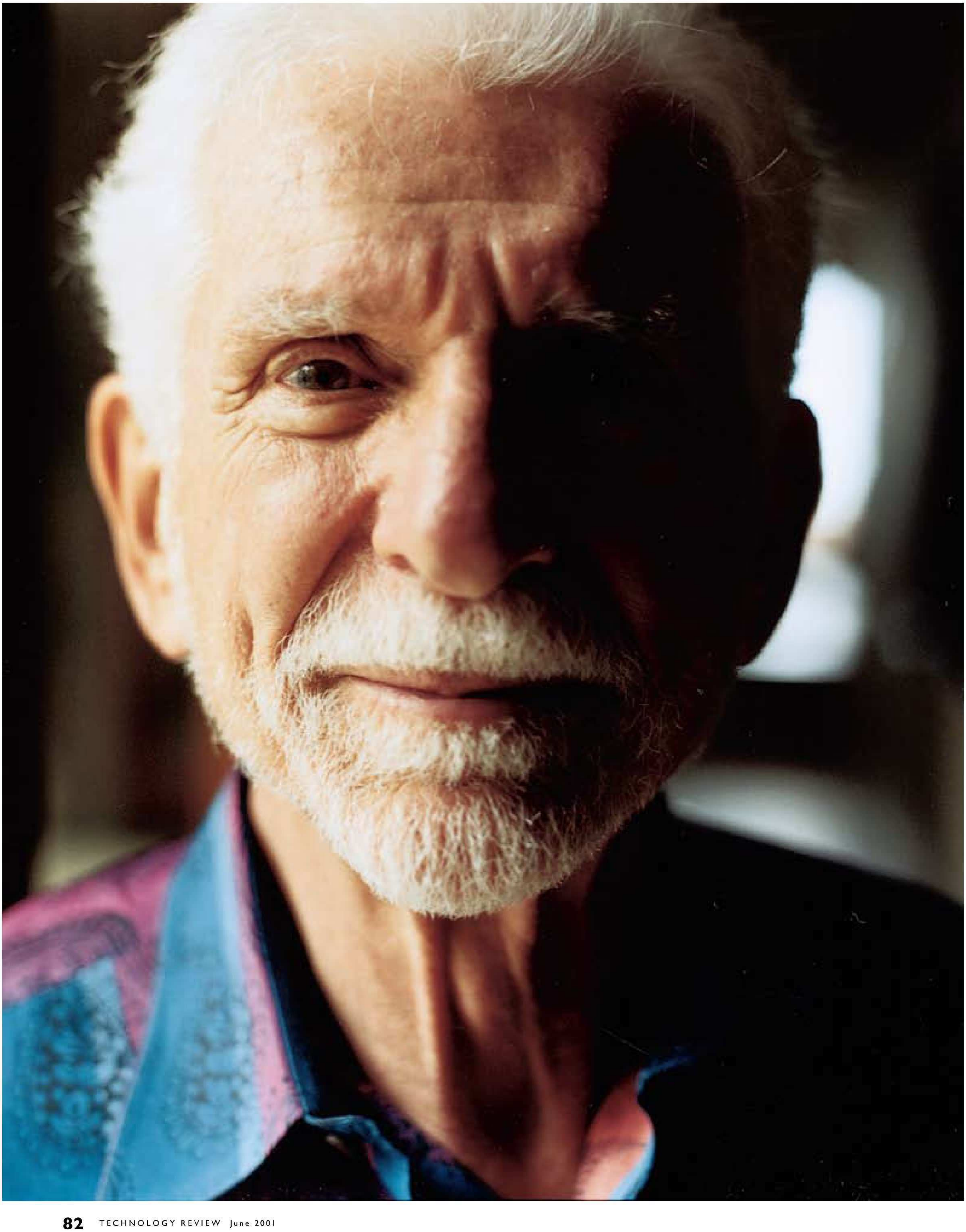
Such possibilities make for heady times from Detroit to Munich. But several issues could roadblock telematics' promise. None is potentially more important than legislative efforts to curb driver cell-phone use for safety reasons. Portugal has banned drivers from using mobile phones, even headset or speakerphone models, and several European countries enforce hands-free rules. Similar action in the United States—especially if it limits how much data drivers can receive—could put the brakes on telematics development.

All car companies are expressing concern. Last fall, Ford Motor announced plans to build a $10 million simulator lab at its sprawling research facility in Dearborn, MI, to study how much information and what type—aural or on-screen—drivers can safely handle. Explains Mike Shulman, principal staff engineer of Ford's vehicle electronics systems department, "What we worry about is this 'cognitive load' that people talk about.... We worry, what is that going to do with safety?"

Industry watcher Heidingsfelder argues that the fact car companies are only now seriously asking such questions may slow telematics' adoption. And there are other curves in the road ahead. Making the technology robust is one, acknowledges DaimlerChrysler's Buckley. "The concept cars, we never drive them over 39 miles per hour. But do high bandwidth and voice recognition work as well at 70 mph, with the windows down?" There's also the question of what people actually want. The automakers' consumer studies show widespread interest in navigation and emergency assistance. But paying extra for Internet access or e-mail interests far fewer drivers.

This is why, grand visions aside, some in the field feel telematics will evolve along the same lines as airbags or antilock brakes: essential, good selling points, but rarely used. "Some people buy an airbag system, and they never experience it their whole life, but by God they wouldn't buy a car without it," says Ralph Wilhelm, the recently retired product-line manager of worldwide telematics for Delphi Automotive Systems, a prime supplier of OnStar's inner workings. The same, he expects, may hold for telematics, with people using it in a pinch, but avoiding most applications.

In some senses, it hardly matters. Because either way, more applications are coming—and for better or worse the car will be increasingly linked to the rest of our information-rich lives. Which means hitting the road to get away from it all will be harder and harder to do. Unless you want a quiet place to check e-mail. ◊



"EVERY-ONE IS WRONG"

A Conversation with Martin Cooper

Photographs by Angela Wyant

The inventor of the portable cell phone didn't carry one until they slimmed down to 100 grams. Then again, he's a rebel in almost every way.

Marty Cooper literally comes down from the mountaintop for our interview, arriving ten minutes late and a little out of breath after skiing all day at Vail. He apologizes and pulls off a sweater before sitting down. "It was tougher territory than I expected," he says exuberantly.

Mountaintops suit Cooper well—the septuagenarian might well be dubbed the Moses of cellular telephone service. In 1973, while at Motorola, he led the development of the first portable cellular phone. In doing so he delivered the market from AT&T, which had first conceived of cell telephony and had lobbied the Federal Communications Commission for retaining a monopoly in using the technology.

Cooper is no stranger to tough territory, either. His company, ArrayComm, is championing a radically different vision for the future of broadband wireless networks, a vision that flies in the face of the incremental progress being eked out by telephone companies worldwide.

Rather than building on existing cellular networks, Cooper argues, wireless data networks of tomorrow need to have new technology to support them. ArrayComm's "smart antenna" technology deploys proprietary software and antenna arrays that are able to target recipients of transmissions precisely. It can then allocate bandwidth to carry those transmissions between two points, rather than broadcasting signals in every direction, as conventional networks do.

The FCC has granted ArrayComm use of spectrum to conduct a market trial in San Diego later this year. The trial will make use of devices developed by both Sony and ArrayComm to deliver not only telephone service but also Web access.

Down off the mountaintop, Cooper spoke with *TR* senior editor Claire Tristram about many subjects, including ArrayComm, why there's hope for the FCC, how many different mobile wireless devices the world has room for, and why competition is critical in the telecommunications industry.

TR: What was it like developing the portable cellular phone?

COOPER: AT&T at the time thought they should have a monopoly on cellular services. We disputed their position that one company should run this business. Also, AT&T's vision was to make car telephones. People don't want to talk to cars. They want to talk to people. At Motorola we were working on all sorts of devices, among them a truly portable phone. We went to Washington and did nothing for two weeks but show our phone to anyone who would watch. Then we did a public demonstration in New York, where we put a station up on a building and walked the streets and invited people to try it. That was April 1973. The whole experience led me to understand why competition is so important in the phone business.

TR: Why is competition so important?

COOPER: Because no one company is going to be wise enough to come up with all the answers. Look, for all practical purposes, telecommunications is still a monopoly. Even where it is not, you still get monopolistic thinking. The telephone industry is a hundred and twenty-five years old. Wireless is a hundred and five years old. Instead of saying, "What are the needs of the people?" or "How can we make people's lives better so they'll want to pay us?" we get off on these technological tangents full of acronyms, like CDMA [Code Division Multiple Access] and 3G [third-generation wireless] and WAP [Wireless Application Protocol]. Everyone is talking about technology, when what's important is what people *do* with technology. Without real competition you don't have much in the way of creative new services.

TR: Yet there seem to be a lot of new and creative wireless services springing up, particularly in Europe and Japan.

COOPER: That's a myth. Europe and Japan seem to be ahead of the United States in some ways just now because they've rammed through some standards. In Europe the big phone companies got together and developed a standard by committee. That's just not the way to win, ultimately. In the U.S. we have four standards, maybe more. Guess who will choose which will win? The people. The market. In the long run the U.S. will have a much more effective telecommunications industry because of it.

TR: What is your vision for how wireless data networks will evolve?

COOPER: The real question is, how is this industry going to evolve into a healthy competitive situation, when today it's so

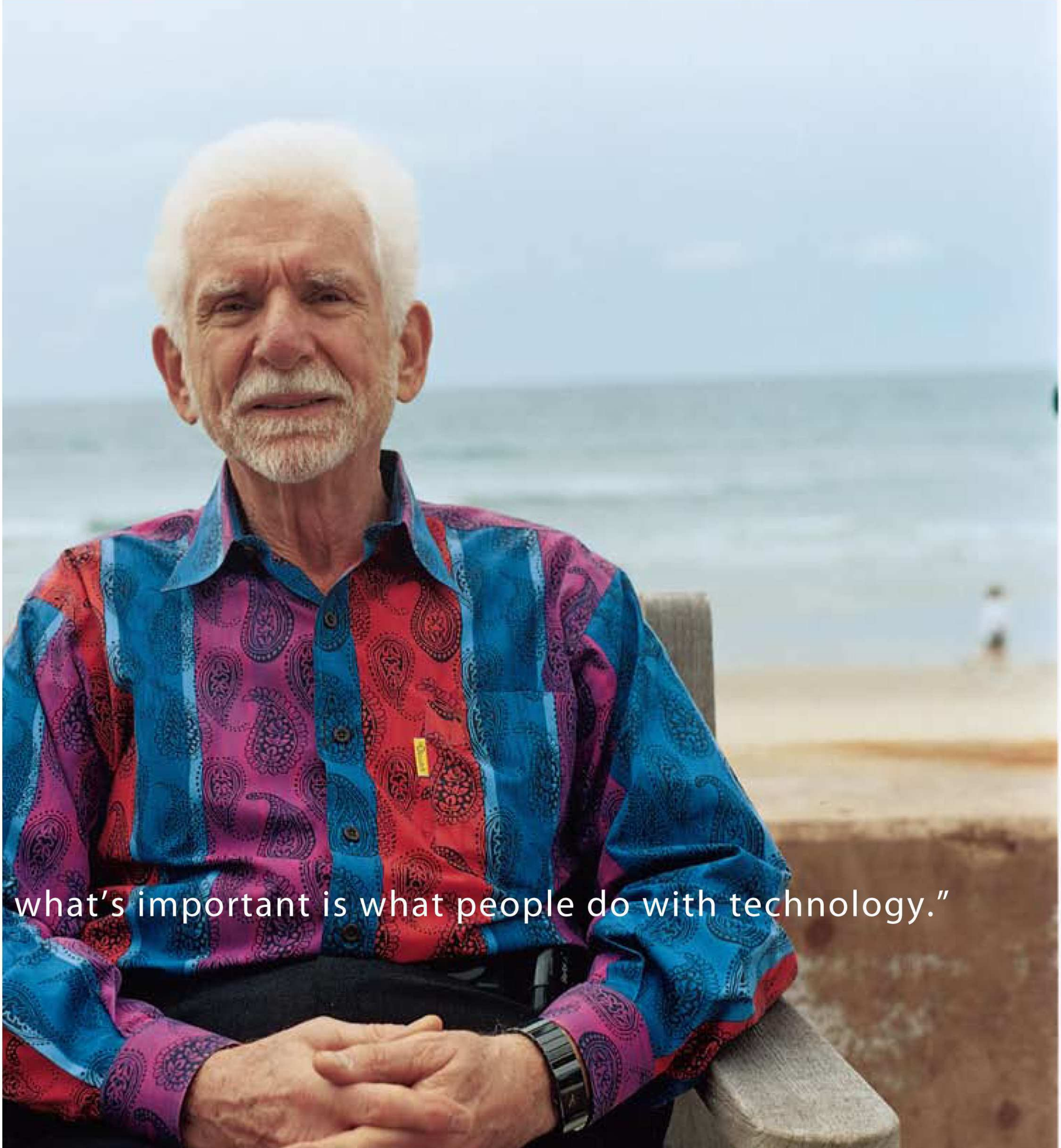
"Everyone is talking about technology, when

mired in monopolistic thinking? We're very fortunate that the Internet has come along. The Internet is full of people trying to figure out what customers want. The Internet is going to force the telecommunications industry to wake up.

TR: How will the Internet force the telecommunications industry to change?

COOPER: What you have now in the cellular market is a lot of carriers going after markets that generate the most revenue and ignoring everyone else. The whole focus is on people who use a lot of minutes. So what happens to old people? To teenagers? To police departments? To all the billions of people in the world who don't fit the profile?

But the Internet creates a situation where an aggressive company can attack a very small market and make a business out of it. It will engender a bunch of different applications and markets. Some people will be good at managing customers and delivering value. Others will be great at building the pipes, the bits and bytes that make this stuff work.



what's important is what people do with technology."

TR: Yet big companies have a huge edge over newer players in spectrum auctions.

COOPER: Well, that's right. Governments have been auctioning spectrum off to the highest bidder, which favors established players, not risk-takers. We're on a campaign to persuade the FCCs of the world to make some provision for innovation, and for services not provided by these behemoth organizations. We're having some success. It turns out that the FCCs of the world really are trying to use spectrum in the best way to serve people. Our market trial [in San Diego] will be important to establish just what we have to offer. Spectrum is essential to what we're trying to do. It's a good thing that our particular technology doesn't need much.

“We’ve been way too impatient with Internet technology.”

TR: Tell me a little bit about what you see people doing with wireless networks. Will it be an extension of what we’re doing already on our desktops, or will we be doing new things in new ways?

COOPER: First you have to get rid of the idea we’ll be accessing the Internet via cell phone. The laughable part of that idea is, here we have this huge power in the Internet, and we’ve only tasted a shadow of it, and yet people insist it will be delivered to us over the cell phone. No. My vision is that you deliver the real, full Internet to people wherever they are. You’re not tied to a desk. You don’t need to be computer literate or know how to find an ISP or a portal or whatever. It has to be wireless, and it has to be ubiquitous, so wherever you happen to travel, it’s there. It has to be available when you need it. No nonsense about dialing in. And it has to be low in cost.

Once all those things are in place, remarkable things can happen. We’ll take a picture with the push of a button, and in seconds it will appear on our Web site for our friends and family to enjoy. Or say you want to hear a John Denver song. You can tell how old I am by my example. You’ll download a five-minute song in 20 seconds directly to a device that plays the song. That will happen. Or games. Imagine a kid in Shanghai and a kid in Cleveland, playing together with absolutely no geopolitical barriers. Someone still has to figure out how to charge you for all these things, but they will.

TR: But no one now is making money even in wired broadband. How will the industry solve its cash flow problems?

COOPER: If you think about it, we have a bunch of problems. The biggest problem is people’s time. It’s a commodity in short supply. People have been bombarded with all these new things. Is there a model that says you can make money through advertising? Sure. Radio and TV work that way. But when everyone jumps on that model at once, it doesn’t work, because people just don’t have the time to pay attention to it all.

But there’s another way to make money, that doesn’t rely on advertising. What if you have something that does useful things for people, that replaces the old way of doing things, and that is more productive and safer and easier than before?

TR: When do you predict these services will take hold and companies begin to make money?

COOPER: It takes a long time for people to change their habits, which is another reason these businesses are failing. I can’t conceive, myself, of buying groceries over the Internet. My grandchildren will do this stuff without even thinking about it. We’ve been way too impatient with this technology. It takes a long time before something becomes popular. How many years do you think it took from the time the first microwave oven was available until you could be fairly certain your neighbor had one? Nineteen years! Almost every new thing has taken that long. The whole Internet thing is only five years old. People are saying it’s a failure. Wait a second. A lot of things really are going to take a generation. They’re going to take people growing up with this tool.

TR: So we’re not going to really see a broadband revolution until 2014?

COOPER: To really achieve the potential of the Internet, yes. It’s going to take longer than anyone thinks. Of course there will be progress along the way. I’m talking about people being connected to a full Internet, wherever they are, carrying three, four, five different devices, maybe even having a couple of telemedicine sensors connected to two different places monitoring their health. Yes. That will take a generation.

In the interim there will be a lot of stuff in the gadget category. Like personal digital assistants. They still aren’t as convenient as they need to be. I should be able to update the calendar in my PDA and have my computer at home and my secretary’s computer automatically update themselves, without me needing to be in the vicinity to establish an infrared link. It takes a long time to get these human-to-computer interfaces right. People are always saying I invented the cell phone. But I didn’t carry one myself until it got down under four ounces. Before that cell phones just weren’t convenient to me.

TR: What keeps you personally fomenting revolution?

COOPER: I guess I must be an optimist. There is no such thing as an easy business, you know. They’re all hard. You need to create a vision, to get people who have money to give it to you, and to overcome all sorts of insurmountable obstacles. They always come and they’re always unforeseeable. If you understand that in the beginning, it helps when you’re in the thick of it.

TR: If you could pick the one thing everyone has wrong right now in the wireless industry, what would it be?

COOPER: I only get one shot at this? Okay. It’s the concept of universal solutions. In other words, people think you can come up with one universal gadget or system or solution that solves a whole bunch of problems. That if you find the Holy Grail of solutions then everyone will flock to you. In my business right now they’re inventing what they call the “next generation of cellular networks,” and they have the temerity to claim it will do everything. They’re saying, “look, we’re going to combine cell phones and personal digital assistants into one device, because everyone is carrying both of these things already, so obviously we all want one device that does both.” That’s crazy!

TR: Yet it does seem to be what everyone thinks is going to happen—that people will gravitate toward a handful of devices.

COOPER: Everyone is wrong. People are different. They have different needs. They’ll need different devices to satisfy those needs. I see a proliferation of gadgets, all of which interconnect. Some gadgets will combine, but more will be separate. There won’t be a universal network, either. Some will be optimized for voice. Some will be for international travelers who need to communicate all over the world. Some will just work around the neighborhood. The suggestion that all of us should be served by one solution is just insane. In my world, there will be lots of companies all battling to make you happier, healthier and more prosperous, with the companies themselves getting prosperous in the meantime. It’s going to happen. I guarantee it. ◊

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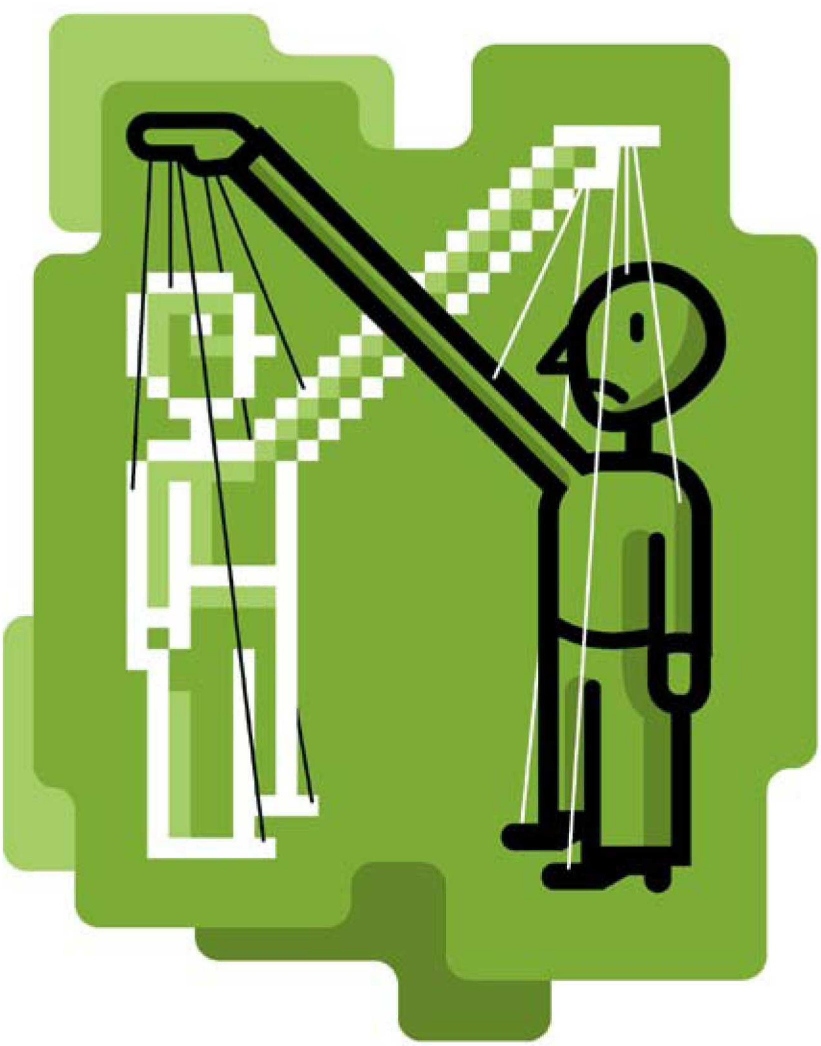
May the Best Interface Win!

Amazon.com may not be the model of financial prosperity, but its Web site is one of the Internet's best shopping locales. By making its online store easy to navigate and use, Amazon has created an environment where money is easy to spend. The company may still be months—or years—from significant profitability, but that didn't stop its customers from buying more than $2.7 billion worth of goods last year.

With all that money pumping through Amazon's site, you'd think that other online retailers would take notice. Not true! Most companies still have tremendous difficulty building Web sites that are easy to use—despite years and billions of dollars spent trying. Considering the money that stands to be gained, you would expect that more companies would be following Amazon's lead.

Take something as simple as electronic shopping carts. Last fall, when Amazon changed its privacy policy to claim ownership of its customers' personal information, I decided to protest by giving a competitor, CDNow, a try. I was impressed by how CDNow let me search for albums by artist, record label, and album and song title, and I liked being able to hear 30-second samples of the songs over the Web (even though the sound quality was pretty poor). On the other hand, CDNow's site was glacially slow; even with my cable modem, it took me 45 minutes to pick out five albums and put them in my shopping cart.



So far, so good. But before I could whip out my credit card and hit the "buy" button, something came up and I had to get up from my computer. The moment had passed. A few days later I remembered that I had never bought my CDs, so I surfed back into the CDNow site. But when I clicked on the cute shopping cart icon, it was empty—my cart had expired. Rather than go back tediously through the CDNow interface, I went over to Amazon, typed in the names of the albums, and then headed for the checkout. Besides the $75 worth of CDs, my shopping cart also contained $150 worth of books that I had picked out a few weeks before but neglected to order. Unlike CDNow, Amazon doesn't throw out the contents of your shopping cart, even if months have passed since you made your selections. This may sound like a trivial detail, but by paying attention to shopping usability, Amazon kept this customer happy—and tripled a sale.

The computer programmer in me says that maybe shopping carts *should* expire—it's a waste of disk space to save data for millions of shopping carts that might never be used again. In a real supermarket, after all, clerks take the food out of abandoned carts and put it back on the shelves. But Web sites are different from physical stores, and disk drives are incredibly cheap these days. For a few hundred dollars, CDNow could buy a disk large enough to store more than a million electronic shopping carts. The company's decision to empty mine cost not only that one sale, but future sales as well.

Along the same lines, consider another dubious, but common, online practice: forcing Web shoppers to type credit-card numbers without spaces or dashes. An overwhelming number of

CHRISTOPH NIEMANN

sites demand that visitors key in a continuous string of 16 digits or more. No spaces or dashes please! This is so commonplace that hardly anyone notices its tremendous inconvenience.

Take a look at the front of one of your credit cards, and you'll see that the account number is printed in four groups of digits with spaces in between. Those spaces are there for a reason: they make the digits easier to read and reduce the chance that you'll get the numbers wrong when you type, speak or otherwise transcribe them. Yet how many times have you tried to use that card at a retail Web site and been forced to cram all the digits together into one box on the purchasing form? And how many times have you had to fill in the box—or even the whole form—a second time because you screwed up the credit-card number on the first go-round?

It's another one of those small details that annoy me as a consumer. This one infuriates me as a programmer, too, but for a different reason: I know that in most computer languages it takes precisely one line of code to remove the spaces from a field of data provided by a user.

Digital River, of Eden Prairie, MN, builds, hosts and manages the Web sites of more than 8,000 clients, including Novell and ScanSoft. The company bills itself as a global commerce service provider. So I called up Digital River and asked why its credit-card processing system doesn't usually let people type credit-card numbers the way that the numbers appear on the embossed plastic.

"Because that's the way we wrote it!" said Marty Boos, Digital River's vice president of information systems. "It's never been an issue for us. We haven't gotten complaints on it."

One reason that Digital River may not get complaints, I explained to Boos, is that the company puts a little note on its Web pages that says "Do NOT use spaces or dashes" when entering credit-card numbers. So clearly the fact that Digital River's computers don't take spaces or dashes has been an issue for the company. Except that instead of reprogramming its computers, Digital River decided to reprogram all of the human beings who use its e-commerce sites.

Well-written software doesn't require that people bend their behavior to the machine; it responds productively to the quirks and foibles of its human users. E-commerce sites, take heed.

Boos didn't see the irony. Instead, he agreed with my assessment. "When given instructions, 99 percent of the customers can [follow them]," he said proudly.

I find this attitude distasteful. Well-written software doesn't require that people bend their behavior to the fancy of the machine; it responds productively to the quirks and foibles of its human users. One nice feature of Microsoft Word, for instance, is that if you type a word with a common misspelling, the program will automatically correct it. Fixing typos, letting people type spaces in credit-card numbers and even letting people type the letters "O" and "l" for the numbers "0" and "1" isn't rocket science.

Unfortunately, most of the universities turning out the next generation of computer programmers aren't spending much time teaching students the art of writing humane, usable software. Undergraduate computer science departments have instead crowded their curricula with the harder aspects of the subject, like data structures and compiler design. I searched for the word "usability" on the Web sites of the computer science departments at Stanford University, MIT and the University of Pennsylvania and came up with nothing. Searches at Harvard University, the University of California, Berkeley, and the University of Washington were slightly more fruitful: each turned up a single homework assignment for a single advanced course that mentioned usability issues.

To be fair, Web searches like this can be misleading. Daniel Jackson, who teaches MIT's undergraduate software-engineering course, says that he tries to introduce the topic of usability from time to time. But it's hard. That's because, Jackson says, before a programmer can create a usable computer system—whether it is a desktop application or an e-commerce Web site—he or she must have a clear conceptual mastery of the task at hand. For many programmers, that is no fun at all—and as a result it frequently gets omitted. "It's much harder to analyze a problem deeply than it is to hack a bunch of code," says Jackson. "Too many software developers don't care about the user enough to care about what problem they are trying to solve. They get too tied up in the joys of their own solutions."

Going back to electronic shopping carts, it's fun to think of clever ways of "garbage collecting" abandoned carts and freeing up space inside CDNow's database server. It's no fun at all to calculate how much space is being wasted on Amazon's servers and how often the company needs to buy new disks and faster database servers to keep up with all of the dead—or dormant—data. Likewise, it's no fun thinking of all the ways that somebody can mistype a credit-card number and trying to make an e-commerce system tolerant of user error.

It would be nice if the financial markets would reward the companies with the best interfaces, but there are so many other factors determining a company's success or failure that usability invariably plays second fiddle to issues like marketing and financial acumen.

But me, I'm rooting for Amazon—and hoping the best interface wins. ◊

VISUALIZE

JAN STALLER

The Telecom System

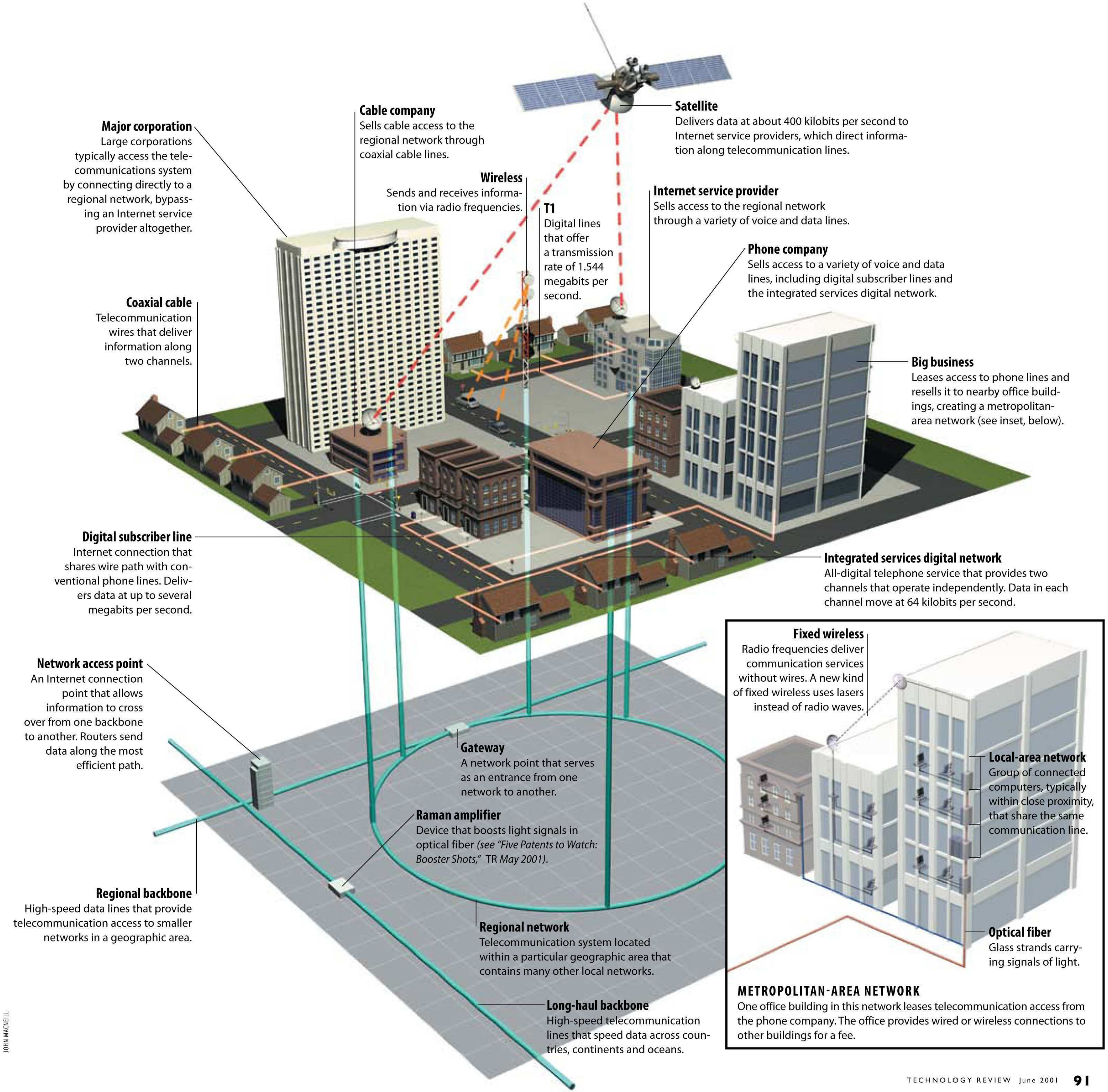
How that e-mail gets to your desk

If Samuel Morse were alive today, he'd be proud. The first U.S. telegraph line, completed in 1844, helped pave the way for America's modern telecommunications network. In the 1850s, telegraph wires crisscrossed the country, connecting hundreds of railroad stations, and by the turn of the century they had made their way to Europe via transatlantic cables. The invention of the telephone, and, later, satellites and computers, expanded telecommunications into virtually every geographical nook and cranny and transformed communicating via Morse's dots and dashes into the exchange of ideas using words and images.

The network today is a mesh of wired and wireless connections, with mobile phones, telephones, television, cable, fax machines, e-mail and the Web sharing much of the same infrastructure. Large transmission lines, known as backbones, link local and regional networks the way interstate highways connect towns and cities. An assortment of sophisticated computer hardware, including hubs, bridges, gateways, repeaters and routers, shuttles information to its destination—around the building or across the world—along the most efficient path. The pathways can be any combination of wired or wireless technology, including copper lines, glass fiber, radio and satellite.

Like any kind of infrastructure that's inundated with traffic, the telecom system has its inadequacies. Decades-old copper wire chokes on floods of information, especially in the areas closest to home—the so-called last mile. At the same time, people want the networks to give them access to more sophisticated forms of communication, including video on demand, videoconferencing and online game playing.

The immediate fix appears to be more or better fiber-optic cable to accommodate broader bandwidths at faster speeds. Better use of wireless technology, including radio, fixed wireless and even laser beams *(see "No-Fiber Diet," p. 51)*, is also attracting attention. For the longer term, advances in a hot branch of physics known as photonics could dramatically expand a fiber's transmission capabilities *(see "The Next Generation of Optical Fibers,"* TR *May 2001)*. But of course, those solutions will last only so long before people crave more data, faster. ◊



JOHN MACNEILL

Convergence? I Diverge.

What's all this talk about "media convergence," this dumb industry idea that all media will meld into one, and we'll get all of our news and entertainment through one box? Few contemporary terms generate more buzz—and less honey. Consider this column a primer on the real media convergence, because it's on the verge of transforming our culture as profoundly as the Renaissance did.

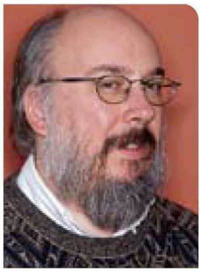
Media convergence is an ongoing *process*, occurring at various intersections of media technologies, industries, content and audiences; it's not an end state. There will *never* be one black box controlling all media. Rather, thanks to the proliferation of channels and the increasingly ubiquitous nature of computing and communications, we are entering an era where media will be everywhere, and we will use all kinds of media in relation to one another. We will develop new skills for managing information, new structures for transmitting information across channels, and new creative genres that exploit the potentials of those emerging information structures.

History teaches us that old media never die. And before you say, "What about the eight-track," let's distinguish among media, genres and delivery technologies. Recorded sound is a medium. Radio drama is a genre. CDs, MP3 files and eight-track cassettes are delivery technologies. Genres and delivery technologies come and go, but media persist as layers within an ever more complicated information and entertainment system. A medium's content may shift, its audience may change and its social status may rise or fall, but once a medium establishes itself it continues to be part of the media ecosystem. No one medium is going to "win" the battle for our ears and eyeballs.

Part of the confusion about media convergence stems from the fact that when people talk about it, they're actually describing at least five processes:

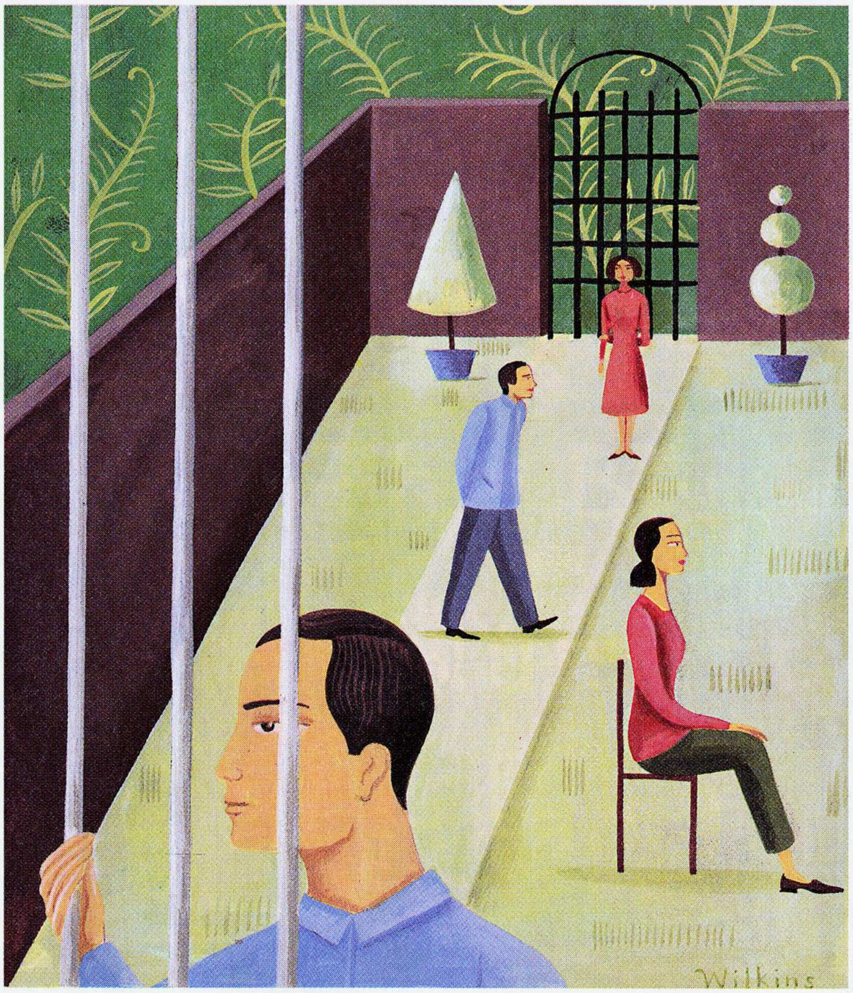
- **Technological Convergence:** What Nicholas Negroponte labeled the transformation of "atoms to bits," the digi-tization of all media content. When words, images and sounds are transformed into digital information, we expand the potential relationships between them and enable them to flow across platforms.
- **Economic Convergence:** The horizontal integration of the entertainment industry. A company like AOL Time Warner now controls interests in film, television, books, games, the Web, music, real estate and countless other sectors. The result has been the restructuring of cultural production around "synergies," and thus the transmedia exploitation of branded properties—Pokémon, Harry Potter, Tomb Raider, Star Wars.
- **Social or Organic Convergence:** Consumers' multitasking strategies for navigating the new information environment. Organic convergence is what occurs when a high schooler is watching baseball on a big-screen television, listening to techno on the stereo, word-processing a paper and writing e-mail to his friends. It may occur inside or outside the box, but ultimately, it occurs within the user's cranium.
- **Cultural Convergence:** The explosion of new forms of creativity at the intersections of various media technologies, industries and consumers. Media convergence fosters a new participatory folk culture by giving average people the tools to archive, annotate, appropriate and recirculate content. Shrewd companies tap this culture to foster consumer loyalty and generate low-cost content. Media convergence also encourages transmedia storytelling, the development of content across multiple channels. As producers more fully exploit organic convergence, storytellers will use each channel to communicate different kinds and levels of narrative information, using each medium to do what it does best.
- **Global Convergence:** The cultural hybridity that results from the international circulation of media content. In music, the world-music movement produces some of the most interesting contemporary sounds, and in cinema, the global circulation of Asian popular cinema profoundly shapes Hollywood entertainment. These new forms reflect the experience of being a citizen of the "global village."

No single medium is going to win the battle for our ears and eyeballs. And when will we get all of our media funnelled to us through one box? Never.



Much as the historical Renaissance emerged when Europe responded to the invention and dispersion of movable type, these multiple forms of media convergence are leading us toward a digital renaissance—a period of transition and transformation that will affect all aspects of our lives. The first Renaissance was a period of political and social instability, and the old monastic order crumbled. Today, media convergence is sparking a range of social, political, economic and legal disputes because of the conflicting goals of consumers, producers and gatekeepers. These contradictory forces are pushing both toward cultural diversity and toward homogenization, toward commercialization and toward grassroots cultural production.

The digital renaissance will be the best of times and the worst of times, but a new cultural order will emerge from it. Stay tuned. ◊



SARAH WILKINS

ESSAY | JEFFREY A. CHESTER

Web Behind Walls

Left unchecked, cable firms will funnel Internet traffic to their own content—and the Web won't be worldly or wide.

THE RECENTLY CONSUMMATED merger of America Online and Time Warner concluded a year-long struggle over the nature of monopoly power and open access in the broadband age. This battle, which pitted consumer advocates and corporate competitors alike against the twin media giants, ultimately yielded several important safeguards. Chief among these: the guarantee of open access to the cable network for rival Internet service providers, a similar provision barring discriminatory treatment of interactive television traffic, and a monitoring system to handle complaints from the new AOL Time Warner's competitors.

But despite such safeguards, another even more important battle looms on the horizon. At stake is the future and form of the Internet for millions of Americans whose access to the online world comes through the set-top portals of cable television. Instead of the multivaried pathways of the World Wide Web, these users will be provided easy access to a much smaller subset of items and options that reflect the network owner's online programming, as well as the offerings of its content partners. Dubbed "walled gardens" by supporters and skeptics alike, these new "managed-content areas" will therefore offer the illusion of online choice, while leading subscribers down well-worn paths of proprietary content and affiliated programming—in stark contrast to the great diversity of expression the Web seemed to promise in its heyday, way back in, say, 1997.

In their filings with the Federal Communications Commission during the merger-review process, AOL and Time Warner offered a chilling glimpse into this new online world by speaking rhapsodically of "next-generation branded content" and "powerful e-commerce applications." Presumably, these will be the financial fruits—for the cable networks and their content partners—of the new walled gardens.

But AOL and Time Warner were much less forthright concerning the nature of these services—because their very existence puts up walls that will separate cable subscribers from the vast expanses of the Internet (or, at the very least, discourage all but the most adventuresome users from straying too far). This is because the underlying architecture of the new cable broadband networks, offered through sophisticated set-top boxes under the guise of "interactive television," will permit network owners to favor their own online fare over that of their competitors. Menus, on-screen icons and the local caching of featured content (to speed its delivery) will all come into play, as the once-level online playing field is tilted sharply toward the network owner's interests.

It was none other than the Walt Disney Company (itself no stranger to aggressive behavior in the media marketplace) that warned of the potential abuse of this power during the AOL-Time Warner merger review. By controlling both programming and the pipes through which that programming is delivered, Disney pointed out, the merged company would have "undeniable economic incentives and opportunity...to favor its own affiliated content and to discriminate against unaffiliated content providers."

That argument worked, at least in part. The strictures ultimately imposed

on AOL Time Warner by the Federal Trade Commission—forcing it to provide unrestricted access to other Internet service providers and interactive television traffic—all but precluded it from exercising such control over its competitors. But the newly formed company reaches only 20 percent of all cable households in the United States, while the rest of the vast and still-growing cable market continues to operate without these restraints. Moreover, judging from the claims of those who will actually be building new interactive TV systems—the networking hardware, software and "middleware" vendors whose products will likely establish the ground rules for the broadband future—the potential for abuse is great.

Consider, for example, ICTV, a Silicon Valley company that makes software for digital set-top boxes. In courting cable company customers, ICTV enticingly extends the walled garden metaphor to include "walled jungles" and "fenced prairies." These virtual gated communities, it un-abashedly states, will reach "beyond a proprietary network to content partners on the Web, while circumscribing access to a defined range of approved Web pages."

A competing firm, Transcast, promises to create a "seamless consumer experience," in which "each component is branded with the partner's logo and identity, enabling the partner to promote their brand for the duration of the user's Internet experience." More brazen still is Cisco Systems (the largest supplier of networking hardware and software), which boasts of technology that will allow network operators to create "captive portals." These will give a cable system owner "the ability to advertise services, build its brand, and own the user experience." Not to be outdone is mighty Microsoft itself, which gets straight to the heart of the brave new online world. Promising full "walled garden support" with its new TV Server platform, Bill Gates's ever-ambitious enterprise promotes the possibilities of "whitelists, blacklists, and auto-generated cookies," the means, presumably, of determining who gets to see which programming, and under what terms.

For millions of households, therefore, the World Wide Web will be neither worldly nor wide. The real danger, of course, is that the online marketplace of ideas under cable's control will become as encumbered with gatekeepers and tollbooths as the world of cable has become. If the Internet follows that sorrowful path, what was once a vast library of information on the Web—good, bad and indifferent, certainly, but also diverse and democratic—will begin to resemble the orderly, limited shelves of a chain bookstore. Bestsellers will abound (especially those with corporate ties to the media conglomerates), but alternative and independent voices may find themselves pushed so far to the margins that we'll lose sight of them altogether.

The marketplace of ideas under cable's control could be as encumbered with gatekeepers and tollbooths as cable has become.

That's just too high a price to pay for the speed and simplicity of what amounts to little more than Internet Lite. In the interests of our democracy, broadband cable companies must be held to a higher standard than that—and the carefully constructed safeguards that preside over the AOL-Time Warner merger should be applied across the board to every cable system that offers telecommunications services.

Jeffrey A. Chester is executive director of the Center for Media Education in Washington, DC. He is planning a new nonprofit group, the Center for Digital Democracy, to focus on noncommercial programming and open access in the broadband era.

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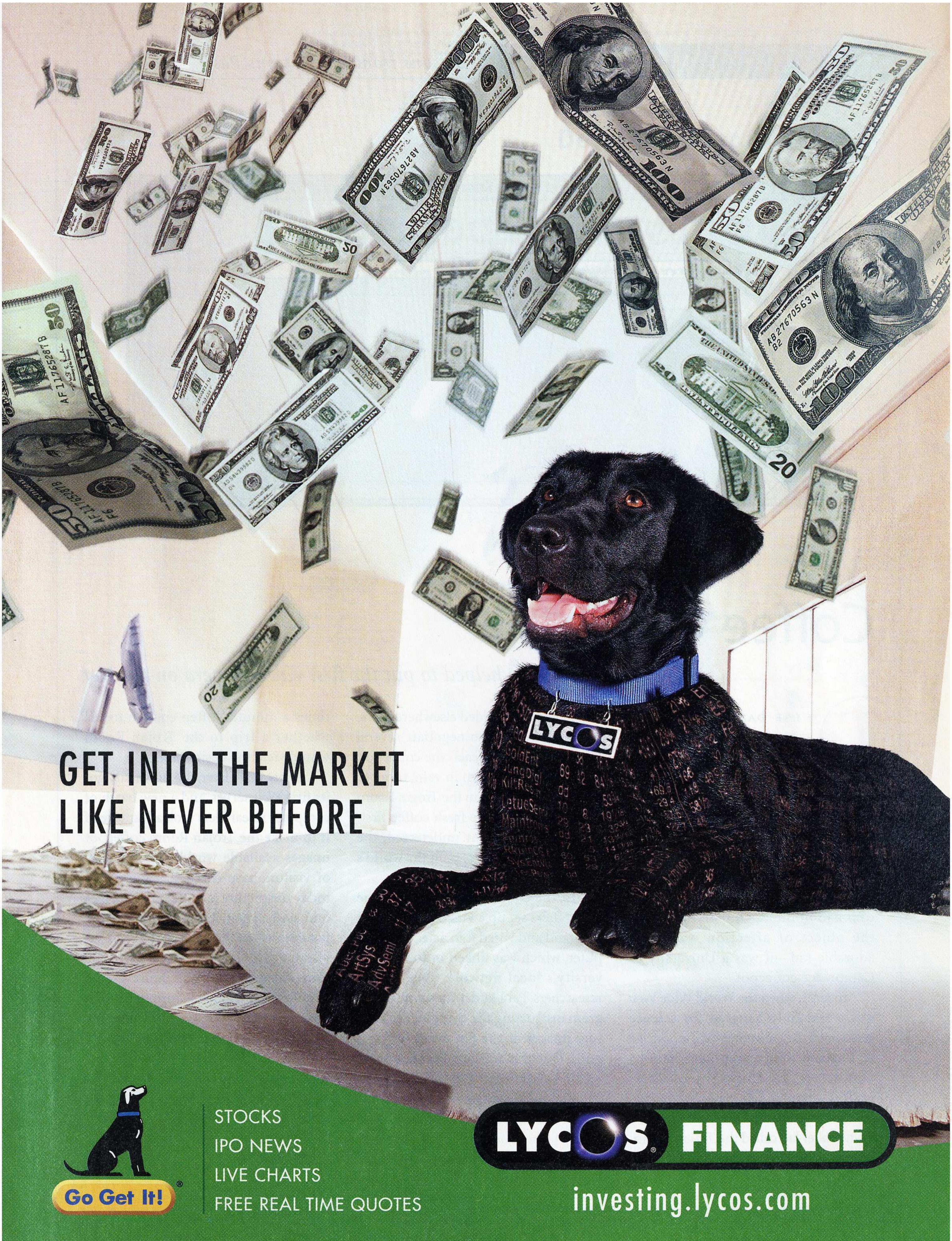
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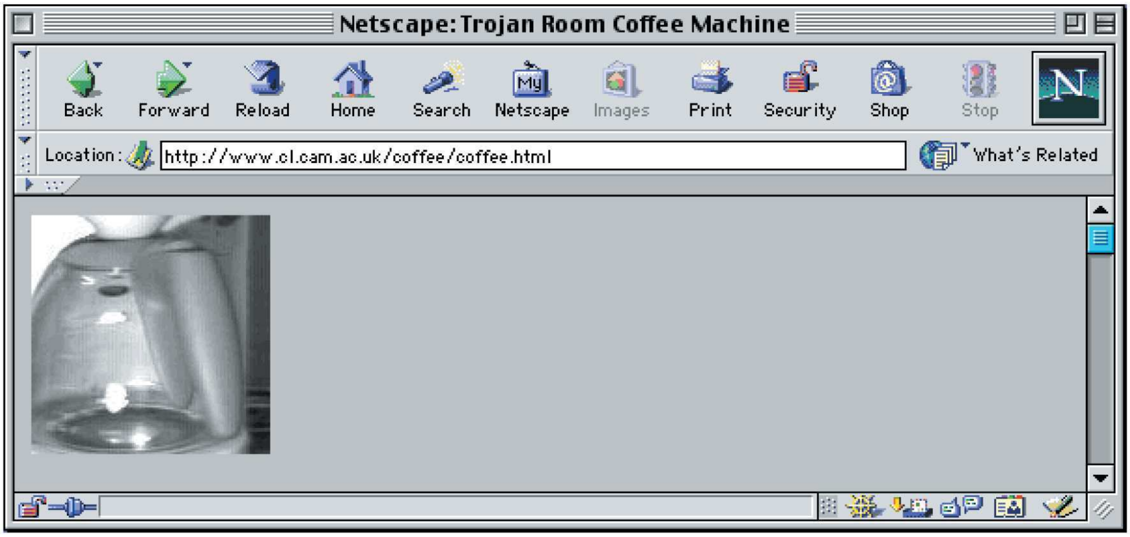

Coffee Cam

A yen for caffeine helped to put the first video camera on the Net

THESE DAYS, ANY PROUD parent with $30 or so can get a webcam for the home computer and use it to share live video of Junior with Grandma and Grandpa over the Internet. Keeping an eye on a distant loved one seems an obvious use for the relatively new technology. In fact, that's just what the researchers who built the first webcam had in mind. Only in their case, the object of affection wasn't an adorable kid—it was a University of Cambridge coffeepot.

In 1991, when the World Wide Web was a text-only hangout for science geeks, and the University of Cambridge in England didn't even have its own Web server, the University of Cambridge Computer Laboratory's sole coffee machine lived in the hall outside a 15-member lab called the Trojan Room. Several members of the Lab's "coffee club," however, resided elsewhere in the building and had to negotiate several flights of stairs to reach the coffeepot. Their trips were often in vain, though, since the hackers from the Trojan Room tended to guzzle the fresh coffee first. Caffeine-starved but undeterred, the remote club members built the world's first networked camera.

In the course of about a day, the researchers set up a video camera on a lab stand and wired it to a nearby computer, which was linked in to the university's local network. One of the researchers, Paul Jardetzky, wrote a program instructing the computer to capture images of the pot every few seconds. Quentin Stafford-Fraser, now at AT&T Laboratories Cambridge, created a complementary program for computers in the remote researchers' own area of the building. The software revealed the pot's status, updated three times a minute—often enough to tell whether a trip to the Trojan Room would yield the desired buzz.

A few years later, the university got its first Web server, and a new batch of computer researchers took advantage of it to make the Trojan Room coffeepot images available worldwide. Millions of visitors have checked it out since: today the picture is updated every second, and a small lamp illuminates the pot even when the Lab is empty so that visitors can virtually check on it any time, day or night. Soon, however, the first webcam will fall victim to history, sped up to Internet time. The University of Cambridge Computer Laboratory will move to new quarters later this year, and the coffeepot and its camera—after 10 years of cult fame—will retire. Until then, you can still grab some virtual caffeine at www.cl.cam.ac.uk/coffee/coffee.html. ◊

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Local technology insight across the globe

Bluestone Software **$525 million** Has been acquired by Hewlett-Packard January 2001	manugistics **$358 million** Has acquired Talus Solutions December 2000	element 14 **$594 million** Has been acquired by Broadcom November 2000	LYCOS Europe **€961 million** Has acquired Spray Network October 2000	SMALLWORLD **$212 million** Has been acquired by GE Powersystems October 2000
NTT Communications **$5.5 billion** Has acquired Verio Septmeber 2000	VASTERA **Undisclosed** Strategic alliance and merger with Ford Motor's US customs operations August 2000	DIGITAL INSIGHT **$140 million** Has acquired AnyTime Access July 2000	NATURAL MicroSystems **$155 million** Has acquired InnoMediaLogic July 2000	ASK PROXIMA **$518 million** Has been acquired by InFocus Corporation June 2000
Peregrine Systems **$2.0 billion** Has acquired Harbinger Corporation June 2000	Buhrmann **Undisclosed** Sale of Information Systems Division to Specialist Holdings Group May 2000	connecta **$1.6 billion** Merger with Information Highway AB May 2000	C-PORT. **$430 million** Has been acquired by Motorola May 2000	MANDATOR **$1.4 billion** Merger with Cell Network AB April 2000
cnet **$736 million** Has acquired mySimon, Inc. March 2000	Maker Communications, Inc. **$1.4 billion** Has been acquired by Conexant Systems March 2000	yesmail.com **$721 million** Has been acquired by CMGI March 2000	BROADBASE **$341 million** Has acquired Rubric February 2000	flycast **$2.5 billion** Has been acquired by CMGI January 2000

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